

Packing a Punch

The Response of the Capital Wealth of Nations to Natural Disasters and Other External Shocks

Candidate 85147

Word Count: 9,999

Abstract

Although the effect of external shocks on physical capital is closely measured, almost no literature extends the analysis to human and natural capital. By reproducing novel measures for all three, this paper measures the response of the capital ‘wealth of nations’ to natural disasters, commodity price fluctuations, and financial aid shocks. Applying a panel vector auto-regression (PVAR) model to 35 countries across the 1985-2011-period, we find empirical evidence that these external shocks have a significant impact on a country’s wealth. However, we also show that non-external factors explain most of the variation in the wealth of nations, and thus point out several avenues for future research.

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Acknowledgements

I am grateful to Dr. Nikola Spatafora for providing his 1985-2011 commodity terms-of-trade dataset, Dr. Inessa Love for making her *pvat*-routine for STATA freely available, and my supervisor, Dr. Cameron Hepburn, for useful commentary and guidance throughout the MSc thesis writing.

Introduction

Over the past four decades, natural disasters and terms-of-trade fluctuations have wreaked considerable havoc across both the developed and developing world. Natural disasters are estimated to occur about once a day somewhere in the world (Laframboise and Loko, 2012). Terms-of-trade woes started with the quadrupling of the petroleum prices in the 1970s (Balassa, 1981), the booms and busts of non-oil primary commodities in the 1980s (Mendoza, 1995), and continued with the recurring busts in oil prices in the mid-1980s and mid-1990s (Funke et al., 2008). From the start of the millennium onwards, both oil and non-oil commodity prices have surged to unprecedented highs, only to be briefly (though abruptly) interrupted by the 2008 financial crisis (Kindleberger and Aliber, 2011). Primary commodity prices were back to record highs again by 2011 (UNESCAP, 2013).

Despite their frequent occurrence across the globe, external shocks continue to have an adverse effect on different countries and regions. Regarding terms-of-trade fluctuations, this is in part due to the asymmetric impact of these shocks; in theory a surge in prices ('boom') benefits countries exporting the commodity while hurting the importers. However, Collier (2002) also finds that (African) countries without diversified are rarely able to take advantage of booms (i.e. a lost opportunity) and adversely suffer from busts (because of their overreliance). Regarding natural disasters, their occurrence over time has been linked to climate change, due to increased concentrations of greenhouse gases causing long-term changes in weather patterns (IPCC, 2007). However, large disasters, which are the focus of this paper, have not necessarily seen an increase. Nevertheless, damages to property and the number of people affected have skyrocketed in the past two decades due to a worldwide relocation of people and expensive infrastructure towards fragile coastal cities (IRIN, 2005, Mendelsohn et al., 2006). Finally, aid flows have known a history of fierce debate regarding the real impact they have on

alleviating the effect of the other external shocks, and that of poverty (Guillaumont and Chauvet, 2001).

The breadth of these shocks to a country's physical stock, population wellbeing, and natural treasures can only be captured in a comprehensive measure that extends further than traditional accounting measures of Gross Domestic Product (GDP) or National Income (GNI). By constructing highly novel measures of physical, human, and natural capital for 35 countries across all continents, we wish to answer the following question in this paper: how does the wealth of nations respond to external shocks?

The Economics of External Shocks: An Overview

This study takes an *ex-post* approach to measure the response of the wealth of nations to the occurrence of natural disasters (geological, climatic, and 'other'¹), commodity terms-of-trade (CTOT) shocks, and shocks in official development assistance (ODA).

Natural Disasters

Natural disasters impact countries *directly*, through the impact they have on physical capital, natural resources, and human suffering; and *indirectly*, through loss of economic activity of economic infrastructure, retracting FDI, and (temporary) diminishing household income (Pelling et al., 2002, ECLAC, 2003).

Regarding the *direct* effects, scholars conventionally argue that certain developing countries are especially vulnerable to external shocks, in particular due to their dependency on primary commodities (UNCTAD, 2002, Collier, 2002), as well as their exposure to natural disasters (Nordhaus and Boyer, 2000), terms-of-trade shocks, and lower adaptation capacity (WorldBank, 2012, Fankhauser and McDermott, forthcoming). Kahn (2005) finds that the average death toll in countries with a lower per capita GDP than US\$2,000 was 9.4 per million persons of the population, against a mere 1.8 deaths for countries with a per capita GDP of at least US\$14,000. This despite the fact that the occurrence of natural disasters is fairly equally distributed among developed and developing countries. Nevertheless, the adverse impact of external shocks on developing countries compared to developed countries is disputed. Several authors show that *internal*

¹ Famines, epidemics, large accidents; refer to the Data section for details.

factors, such as poverty, income inequality, political instability, and internal conflicts could matter as much if not more to the wealth of developing nations (Barnett, 2003, Parry et al., 2004, Raddatz, 2007). Raddatz (2007) finds that more than 90 percent of the variation in GDP per capita is explained by these endogenous events. For developing countries, Raddatz (2007) therefore opts for a shift in policy focus to understanding the causes of internal instability. In a follow-up paper extended to higher income groups, Raddatz (2009) finds that the effect of a natural disaster is highest in the year of the disaster. Building on several other papers, Cavallo and Noy (2010) conclude that the short-run effects of natural disasters are negative.

Other literature points to the adverse effect that *geography* has on growth (Neumayer, 2004, Mendelsohn et al., 2006, Nordhaus, 2006). However, Noy (2009) runs a robustness check on countries with land area in the tropics and actually finds these countries to experience higher growth rates compared to non-tropical countries. He hypothesises this could be due to the occurrence of more crop cycles in tropical countries.

We now turn to the literature on the *indirect* effects. Perhaps surprisingly, scholars in recent years have wondered whether natural disasters could have positive effects. Schumpeter's concept of *creative destruction* has been linked to natural disasters in a hypothesis referred to as the 'productivity effect' (Okuyama, 2003). Countries with outdated, low-productivity capital that are hit by a devastating storm or flood and have this capital destroyed are in a position to replace this destroyed capital with the newest, high-productivity counterparts (Skidmore and Toya, 2002, Crespo Cuaresma et al., 2008). Skidmore and Toya (2002) find a positive correlation between the number of natural disasters and the accumulation of human capital, as well as an increase in total factor productivity (TFP) and GDP per capita. However, Hallegatte and Dumas (2009) argue that the absolute impact of natural disasters is negative, and that claims over some positive 'productivity effect' can only partly offset this. In addition, rebuilding the capital stock by replacing it with newer counterparts generally makes for slow recoveries, causing the negative short-run effects to be more pronounced. Hallegatte and Dumas (2009) state that some countries, in particular developing countries, will be unable to recover fully after the occurrence of each natural disaster, creating path dependencies and poverty traps. Nevertheless, these results are not empirically tested, and therefore causal effects remain absent.

Commodity Price Fluctuations

The relationship between fluctuations in commodity prices and economic growth has been an ever-expanding field of research. This research often quickly focuses on the *resource curse*, or the notion that resource-abundant countries perform worse economic-wise than do resource-scarce countries. Literature reviews by Van der Ploeg (2011) and Rosser (2006) cite several scholars who studied the effect of natural resource price fluctuations. Taking the oil price spikes in the 1970s and 80s as an example, they could have persuaded oil-abundant countries to direct more economic activity to sectors that are oil-intensive. Wages in these sectors will surge likewise, thereby drawing more labour away from other sectors. In addition, more government spending could be directed away from fundamental areas such as education. Consequently, both the country's natural capital (from increased depletion rates) and human capital (from underinvestment in education) could seriously be decreased. However, such claims are nowadays often refuted. As Okruhlik (1999) puts it, '*life did not begin, as many imply, in 1973 with the quadrupling of the oil prices*'; instead, many point out that the effect of resource abundance on growth is endogenous to the quality of a country's institutions (Collier and Goderis, 2007, Brunnschweiler, 2008, Brunnschweiler and Bulte, 2008). This is especially apparent for developing countries, which often do not have the institutional capacity to tap into temporary price booms of their export products (Collier, 2002).

Spatafora and Tytell (2009), who provide the commodity price and shares data used in this paper, find that positive commodity price shocks (called 'booms') are larger than negative counterparts (called 'busts').² Interestingly, the authors also find that the latest boom in their 1970-2008-analysis (i.e. around the start of the 2008 financial crisis) can be attributed in part to the works of a few specific countries, rather than it being completely a global phenomenon. The authors have updated their dataset up to 2011, allowing us to look further at the aftermath of the 2008 financial crisis.

The literature linking commodity price fluctuations to human capital mostly focuses on poverty in developing countries. Bravo-Ortega and de Gregorio (2005) find that only countries with very low levels of human capital show declining growth rates due to their reliance on natural resources; countries above a certain minimum actually prosper. Winters (2005) argues similarly that trade liberalisation increases labour demand

² We do not make distinctions between booms or busts, and will therefore refer to both as 'fluctuations'.

and wages mostly for semi-skilled labourers, leaving the unskilled in peril. Dessus et al. (2008) show that negative real income effects from food price shocks are most profound for households that were already poor before the shock. According to Ivanic and Martin (2008), this is evidently due to the large share of food expenditure in these households' incomes. Urban households, who are net consumers of food, are hit especially. Nevertheless, Winters (2005) claims that trade liberalisation could benefit the entire population of a country when one argues that world prices are more stable than are local ones. However, there are important examples that also refute this claim; China, India, and Indonesia actively enforce trade controls on parts of their domestic food industries. This has prevented exposure by these countries to the 2008 world rice crisis, thereby protecting their farmers from hunger and poverty (Dawe and Timmer, 2012).

Foreign Aid Shocks

Early evidence has pointed out that 'good policy' environments tend to perform better when receiving aid (Burnside and Dollar, 2000). However, this evidence was quickly debunked (Easterly, 2003). Instead, aid is allocated to the most needy, without much effort by the donor to alleviate poverty (Svensson, 2000). Regarding physical capital, Boone (1996) finds no significant differences in investment patterns following aid provision between different types of government. However, regarding human capital, at least three liberal or democratic regimes are found to experience decreasing infant mortality rates, of up to 30 per cent.

Some authors have looked at occurrence of natural disasters and their effect on international aid flows. Following a hurricane in the Caribbean or Central America, Bluedorn (2005) finds that international aid and foreign remittances cause the current account-to-GDP over the medium-term (3-8 years) to be in surplus of 2.7 percentage points, up from a negative initial impact of 5 percentage points. Similar results are found by Yang (2006), although the positive effect of multilateral aid flows in richer countries is generally offset by a net outflow of private FDI. Contrastingly, Raddatz (2009) finds no significant evidence of a diminishing effect by aid flows on the impact of disasters. Concerning interactions with commodity price shocks, Collier and Dehn (2001) find that the effect of negative (commodity) terms-of-trade shocks on poverty can be mitigated in part by an increase in foreign aid. However, the authors also find that hardly any aid has been allocated in this way.

Overall, the current literature shows mixed results for the shocks considered here. We expect natural disasters to especially hit the less-developed countries in our sample. Following the aid development results, we do not expect aid flow shocks to warrant much significance. Commodity price fluctuations will likely have the most pronounced impact, though the sign of the impact is still uncertain.

Gaps in the Literature

The extent of the current literature still leaves many opportunities for improvement. Before Raddatz (2007; 2009), hardly anyone studied the effects of external shocks in a dynamic fashion. In addition, Raddatz provides one of the first large impact analyses of natural disasters. He and Noy (2009) are one of the first economists to study the effects of natural disasters *ex-post*. Nevertheless, both authors solely look at the effect of external shocks on real GDP growth. As has been recently argued, GDP offers an incomplete estimate for a country's wealth (Dietz and Neumayer, 2006, Stiglitz et al., 2010, World Bank, 2012). Cavallo and Noy (2010) conclude that virtually any paper looking at the output effects of natural disasters adopts this narrow measure.

This paper is the first to our knowledge that looks at widespread wealth impacts by considering comprehensive measures for physical, human, and natural capital. Especially the latter two capital types have only very recently been developed; natural capital in Arrow et al. (2012) and the *Inclusive Wealth Report* (2012); human capital in Liu (2011). Our *ex-post* approach allows us to measure the foregone wealth due to a wide range of external shocks, and can provide policymakers with useful insights into the critical parts of their economy.

Methods and Data

External Shocks

a) Natural Disasters

Natural disaster data are taken from the *Emergency Events Database* (EM-DAT, 2012). In a literature overview, Cavallo and Noy (2010) show that the EM-DAT database is used in almost all empirical work.³ The database registers all disasters in which *i*) at

³ A notable alternative is the *Munich Re Natural Catastrophe* database. Fankhauser and McDermott (forthcoming) and Neumayer et al. (forthcoming) both prefer Munich Re, as it is richer in detail and

least 10 people are killed, *ii*) at least 1000 people are reportedly affected, *iii*) a state of emergency is declared, or *iv*) an international assistance is called for. We refine these disasters following Raddatz (2007; 2009) and Skidmore and Toya (2002), who only include those natural disasters large enough to fit the IMF (2003) criteria of: *i*) affecting half a percent of the country's population by the least; *ii*) causing damages amounting to at least half a percent of national GDP; or *iii*) causing at least one deadly casualty per 10,000 people of the population.

Furthermore, Raddatz (2009) conveniently group natural disasters into three larger classes:

Geological disasters – i.e. ground earthquakes, tsunamis, volcanic eruptions, storm and landslides (dry and wet) – are generally immediate and unpredictable in time of impact;

Climatic disasters – i.e. general floods, droughts, extreme temperatures (heat wave, cold wave, extreme winters), and storms (cyclones or local storms) – are typically long-term in their onset and are better predictable;

Other disasters – including famines, epidemics (bacterial, parasitic, or viral), insect plagues, wild fires, and accidents (miscellaneous, industrial, and transport).⁴

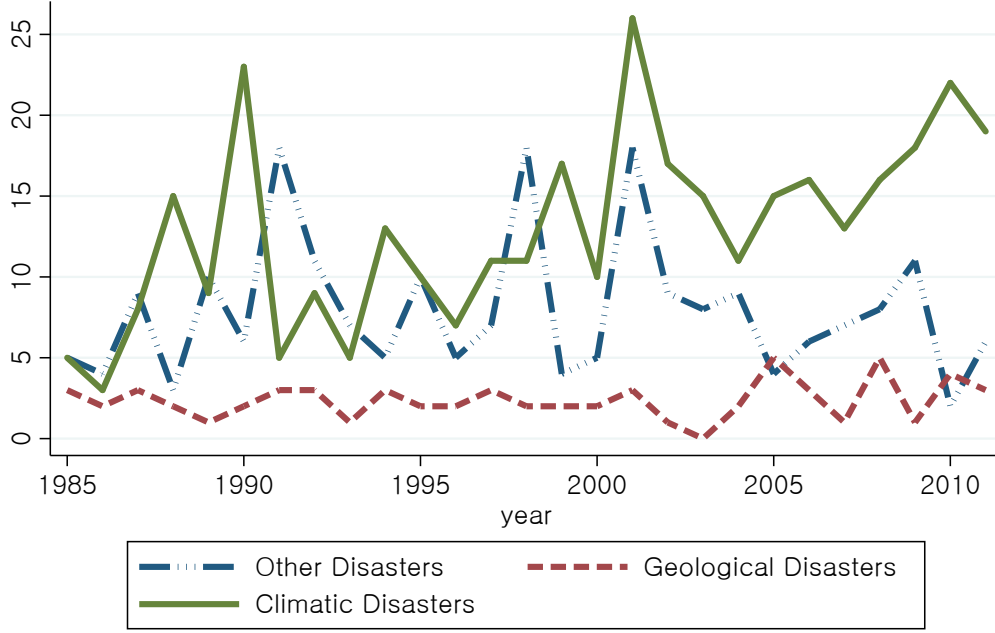
Figure A shows the occurrence of each disaster across time for our sample of 35 countries. There only seems to be a clear upward trend in the occurrence of large climatic disasters, which is in line with the IPCC (2012) and Cavallo and Noy (2010).⁵ However, natural disasters only occur in 13 countries of our sample (Table F, Appendix D). This is not solely due to the strict classification of large natural disasters; it is also due to the loss of observations when composing the wealth measure. Future research should attempt to improve this measure in order to expand the sample.

coverage than is EM-DAT. However, Munich Re is publicly available only from 2004 onwards. In addition, we believe we already make a reasonable effort of considering a disaster's magnitude (a critique by Fankhauser and McDermott on some authors) by applying the IMF's (2003) criteria. The use of Munich Re could perhaps be considered post-thesis.

⁴ Though some of these disasters, such as accidents, are not natural disasters, they are added as control variables.

⁵ By allowing for smaller natural disasters, the frequency of occurrence does show a clear upward trend (see EM-DAT database)

Figure A. Occurance of Natural Disasters



Note: Figure based on 919 observations across 35 countries

b) *Terms-of-Trade Shocks (Commodity-based)*

The original Deaton and Miller (1995) commodity price index, updated by Dehn (2000), is given as follows:

$$DM = \sum_i P_i^{W_i} \quad \text{with} \quad W_i = \frac{P_{ji} Q_{ji}}{\sum_n P_{jn} Q_{jn}} \quad (1)$$

Where P_i is the international commodity price for commodity i expressed in dollars, W_i the value of commodity i as a ratio to the total value of all commodities n , and subscript j the base year. This paper adopts a slightly different version of the DM measure as constructed by the IMF's Spatafora and Tytell (2009). Their *commodity terms of trade* (CTOT) measure takes into account both import and export commodity prices, and focuses on the difference in the importance of commodities to a country's total economy:

$$CTOT_{it} = \frac{\sum_j (P_{jt} / MUV_t)^{X_{ij}}}{\sum_j (P_{jt} / MUV_t)^{M_{ij}}} \quad (2)$$

Where P_{jt} is the price of commodity i , MUVt is the *Manufactures Unit Value Index* that is a deflator, and X_j and M_j are the shares of exports and imports respectively of commodity j in country i 's GDP. Spatafora and Tytell (2009) find the smallest differences between the conventional DM index and their CTOT index for fuel exports, larger differences for non-fuel exports, and the largest differences for non-commodity exports. Consistent with Dehn (2000), export and import shares are constant over time so that the CTOT index only measures commodity price changes. On the one hand, this biases the measure in the case of new discoveries in reserves. On the other hand, it removes Endogeneity issues arising from the mutual dependence of quantities and prices (Dehn, 2000).⁶

Finally, the change in CTOT is as follows:

$$\frac{\Delta CTOT}{CTOT} \approx \sum_j (X_j - M_j) \frac{\Delta(P_j / MUV)}{(P_j / MUV)} \quad (3)$$

Hence, the change in a country's commodity terms of trade is approximately equal to the change in individual commodity price shares.

See Appendix A for data sources. Note that only world prices are used. Following Winters' (2002) and Dawe and Timmer's (2012) findings, we might therefore underestimate or overestimate the volatility of commodity prices for autarkical countries. We acknowledge these worries, but rely on world prices due to data availability issues.

c) *Financial Aid Shocks*

Financial aid movements are identified as changes in the value of aid flows as a percentage of Gross Domestic Income (GDI). Raddatz (2007) argues for the use of GDI instead of GDP, because GDI better captures the ability of (low-income) countries to repay debt or buy imported capital, which is affected by, say, CTOT shocks. By a similar reasoning, GNI also accounts for non-domestic trade that GDP ignores, offering better estimates of the income available to a country's population. Note that this variable is correlated with the financial wellbeing of developed countries (Yang, 2006). Appendix A describes the data sources.

⁶ For example, Wright (2011) cites the influences of technological progress and the role of buffering stocks.

Physical Capital

Following the *2012 Inclusive Wealth Report* (2012), we estimate physical capital according to the perpetual inventory method (PIM). With PIM, changes in physical capital occur due to changes in the annual *net* capital formation (i.e. the share of gross investment in GDP adjusted for depreciation and GDP growth). Hence, it is arguably the best tool to study the dynamics of physical capital. The most critical point in this estimation is choosing the initial capital stock. We have to assume that the manufactured capital stock in this initial period is in its steady state, which is a strong assumption and has a potential bias. However, we minimise this bias by calculating the average capital stock over 1960-1970, and depreciating this at a fixed annual rate of 7 percent. Because our sample period starts no earlier than 1985, the depreciated initial stock will account for only 26 percent of the capital stock in 1985, and a mere 2 per cent by 2010.

The PIM approach is described in King and Levine (1994), and starts with defining a country's growth rate:

$$\gamma_{it}^* = \lambda \gamma_{it} + (1 - \lambda) \gamma_t^w \quad (4)$$

where γ_{it} is country i 's GDP growth rate, γ_t^w is the world GDP growth rate, and an assumed weight (λ) of 0.25. We use a constant version of this growth rate to compute the steady state capital-output ratio for the 1960-1970 period:

$$\underline{k}_i = \frac{\underline{I}_i / \underline{Y}_i}{(\delta + \underline{\gamma}_i)} \quad (5)$$

where $\underline{I}_i / \underline{Y}_i$ is a country's investments as a ratio of GDP, i.e. gross fixed capital formation. This ratio is transformed into *net* terms by adjusting for two dynamics familiar to neoclassical growth models (King and Rebelo, 1999): δ_i is the 'geometric' depreciation rate⁷, and $\underline{\gamma}_i^*$ the average country output growth rate over 1960-1970. As can be seen, \underline{k}_i is depreciated in perpetuity, hence the term 'perpetual' inventory

⁷ In other words, the depreciation rate is assumed constant over time. This is done in every paper we read using the PIM approach. It is done out of simplicity, but also out of pure necessity; owners are often unaware of the true value of their capital at a certain point in time, hence data is often unavailable (Blades, 1997).

method; the idea that all assets will always remain part of the capital stock, no matter how far in the future depreciated. Both King and Levine (1994) and Muñoz et al. (2012) from the 2012 Inclusive Wealth Report assume $\delta_i = 0.07$. This might seem large, but is chosen to stress the importance of investment dynamics, and to rapidly decrease any possible bias flowing from the ‘steady-state’ initial estimate.

We then multiply capital-output ratio \underline{k}_{it} with Y_i^0 (the initial manufactured output from 1960-1970) to obtain the initial manufactured capital estimate, K_i^0 :

$$K_i^0 = \underline{k}_i Y_i^0 \quad (6)$$

As we depreciate our capital stock at 7 percent annually, we will retain about 26 per cent of the initial manufactured capital estimate in 1985 and only 5 per cent in 2010. Therefore, we minimise any potential bias. Consequently, physical capital K_{it} is as follows:

$$K_{it} = \sum_{j=1}^t I_{ij} (1 - \gamma_{it}^*)^{t-j} + (1 - \gamma_{it}^*) K_i^0 \quad (7)$$

Our estimates for K_{it} differ in two respects from the conventional literature. Firstly, we do not keep γ_{it}^* constant over the 1985-2011-sample period, but instead allow it to vary annually. This is because we are interested in capturing shocks in physical capital, which in our view is not possible when assuming constant output growth rates. Secondly, some authors (e.g. the 2012 Inclusive Wealth Report) also include population growth, perhaps for analysing per capita estimates. However, our paper only considers total wealth estimates. In addition, there is doubt as to whether population growth truly affects investments in the capital stock (Pritchett, 1996). We therefore do not adopt population growth in our analysis.⁸ For data sources, see Appendix A.

Human Capital

Measures for human capital are subject to continuous criticism. The usual approach – in which human capital is the simple product of secondary school enrolment and secondary schooling years (growth) – is grossly incomplete, and needs substantial amendment. Arrow et al. (2012) and the authors of the *Inclusive Wealth Report* [e.g. Muñoz et al. (2012)] improve the measure somewhat. They calculate human capital following the

⁸ We also ran our tests with population growth, but found identical results.

Mincer formula. Still, we will not follow their approach. Firstly, the use of the Mincer formula results in potentially large functional form biases. Heckman et al. (2003) find this bias for US census data in the 1980s and 90s. Secondly, it is a strong assumption to make that the return of education is the same in every country. In a comment paper, Hamilton (2012) therefore recommends the richer approach by Liu (2011) who builds on Jorgenson and Fraumeni (1989). Following Liu (2011) and Hamilton and Liu (2013), we therefore estimate human capital through the *lifetime income (LIN) approach*. However, in order to expand the number of countries and years in the sample, we apply rougher measures from the ones used by Liu (2011). Table A lists an overview of the differences.

A person's human capital is given by the following equation:

$$\begin{aligned}
 LIN_{it} = & EMR_{it} WAGE_{it} + (1 - ENR_{it}) \left[SUR_{it+1} (EMR_{it+1} WAGE_{it+1}) \left(\frac{1+r_{it}}{1+\delta} \right) \right] \\
 & + ENR_{it} \left[SUR_{it+1} (EMR_{it+1} WAGE_{it+1}) \left(\frac{1+r}{1+\delta} \right) \right] / EAT_{it}
 \end{aligned} \tag{8}$$

where EMR is the employment rate for individual i in time t , calculated as the total number of employed people as a ratio of the country's labour force; $WAGE$ is the individual annual labour income in *nominal* terms⁹; and ENR is the weighted average of annual secondary and tertiary enrolment rates. To compute the weights, the secondary and tertiary enrolment rates were multiplied by each country's total 15-19 and 20-24 year-old populations respectively (according to the World Bank's methodology), after which the sum of these was divided by the total 15-64 year-old population. SUR are ten-year averaged mortality rates for each country's 15-64 year-old populations; r is the annual wage growth rate; and δ is the annual discount rate. EAT_{it} is educational attainment. Despite the methodological differences with Liu (2011), our human-to-physical capital ratios are generally similar to his.

⁹ We multiply the monthly wage in local currency (LCU) by the annual US\$ exchange rate, and by 12 months.

Table A
Human Capital

	Liu (2011)	De Graaf (this paper)
1. Coverage		
<i>Countries</i>	18	80
<i>Years</i>	11 (1997-2007)	27 (1985-2011)
<i>Age Group</i>	15-39 and 40-64	15-64 (average)
<i>Education</i>	ISCED 0-6	Secondary and Tertiary only (World Bank)
<i>Gender Difference?</i>	Yes	No
2. Measures		
<i>Employment Rate</i>	OECD data (national Labour Force Surveys); rate is assumed 100% when missing	UNSD data; rate is also assumed 100% when missing
<i>Annual Earnings</i>	OECD Education Database and Annual National Accounts	International Labour Organization (ILO); missing values imputed with annual Consumer Price Index (IMF)
<i>Growth Earnings</i>	Geometric mean over 1960-2017 period (OECD <i>Medium-term Baseline</i>)	Year-on-year difference (own calculations)
<i>Discount Rate</i>	Assumed 4.58% annually (following Jorgenson and Fraumeni, 1992)	Similar
<i>School Enrollment</i>	OECD databank, by 5-year age group, assumed only for 15-39 age	World Bank, weighted average of secondary and tertiary for 15-64 age; country averages are imputed for missing values
<i>Survival Rates</i>	<i>Human Mortality Database</i> (by year of age)	<i>Global Health Database</i> (15-64, average)
<i>Educational Attainment</i>	UNESCO; Eurostat; OECD	Barro and Lee (2012); sum of secondary and tertiary educational years

Natural Capital¹⁰

This paper aims to provide comprehensible wealth accounts for the countries in its sample. Especially for the components of natural capital, this was a tedious task to complete (consequently, we refer to all data sources in the main text). Data on rental prices sometimes relies on the expert opinions expressed in one or a few papers, as is the case for fisheries, crop- and pastureland. More details are given for each component in the rest of this section. Note that some components of natural capital are missing or underestimated (also see Footnote 10). For example, ecosystem services appear only implicitly in the value of agricultural land. Aesthetic amenity services ('the beauty of nature') are also excluded, which can be especially substantial in high-income countries (World Bank, 2011). Furthermore, several values for water (recreational and wetland

¹⁰ Due to time constraints, the current analysis excludes wealth from forests (timber and non-timber forest benefits); water; and metals and minerals. Capital stock adjustments, in particular emission damages and total factor productivity, are also not included. Though these stocks could be substantial, our results show that the current estimate for natural capital is able to respond logically to our selection of external shocks.

ecosystem services, growing scarcities, and hydropower) are not included in the analysis. Finally, certain minerals, such as uranium, lithium, and diamonds, miss reliable data on proven reserves and rents (World Bank, 2011). We understand that our natural capital estimates are therefore incomplete, and applaud initiatives such as the *Wealth Accounting and Valuation of Ecosystem Services* (WAVES, 2012) to enable policymakers to fully account for the value of these critical parts of nature.

We apply the methodology formulated by Arrow et al. (2012) and the 2012 *Inclusive Wealth Report* (Muñoz et al., 2012) to estimate wealth from the different components of natural capital:

$$RPA_{it} = \frac{1}{A} \sum_k R_{ik} \cdot P_{itk} \cdot Q_{itk} \quad (9)$$

Where RPA_{it} is the rent per spatial unit (hectare, tonne, etc.) for country i in year t , R_{ik} the constant rental rate (i.e. the profits, expressed as a percentage of price P_{itk})¹¹ for crop/resource k , P_{itk} the per-unit price of k , and Q_{itk} the production of k . A is the total annual harvested area of the crop/resource in question. We then estimate:

$$Wha_{it} = \sum_{j=0}^{\infty} \frac{RPA_{it}}{(1+r)^j} \quad (10)$$

where Wha_{it} is the present value of discounted rents per spatial unit, r the discount rate, and j the planning horizon for the land, here assumed to be infinity (i.e. we discount in perpetuity). We take this present value of discounted rents as a proxy for the shadow price. Arrow et al. (2012) and the 2012 IWR choose to estimate *constant* shadow prices by averaging wealth per hectare over their sample period. However, we are interested in measuring shocks to wealth in this paper, and therefore allow our shadow prices to vary annually. Finally, the total wealth of a natural resource class is a product of the shadow price of country i and the world's remaining stock/area of the natural resource component in year t , as follows:

$$Wealth_{it} = Wha_{it} \cdot Area_{it} \quad (11)$$

¹¹ We consistently use different sources for rental rates than the 2012 IWR, who rely on detailed rental rate data by Narayanan and Walmsley's (2008) *Global Trade Analysis Project* (GTAP) database. This database is costly, and was unavailable for use in this paper.

a) *Agricultural Land: Cropland*

Rental data for agricultural land commodities is poorly available, and if available, of poor quality. The best freely available measures to our knowledge are provided in Appendix 1 of the World Bank's report "*Where is the Wealth of Nations?*" (2006), which has rough rental rates for the nine largest crops based on revenue or production: rice, maize, wheat, soybeans, coffee, bananas, grapes, and apples and oranges. Rental rates for other crops are assumed to be 80 percent of the weighted average of the first three crops. Correspondingly, we use production values ($= \text{price} * \text{production}$) for rice (Thailand), maize (world), wheat (Canada; US), soybeans (world), coffee (Arabica; Robusta), bananas (US), and oranges (France) from the World Bank's *Global Economic Monitor (GEM) Commodities*. Following the World Bank (2006), we find production values for all other crops by subtracting the production value ($= \text{price} * \text{production}$) of our nine large crops from the total production value of crops. Having the production values, we multiply these by the calculated rental rates, and then sum everything together per country per year. This sum is then divided by the world's annual crop production [taken from the *FAOSTAT Database* (FAO, 2013)], ending up with a world-averaged rental rate per hectare of cropland [see equation (9)]. This rental rate per hectare is discounted in perpetuity at a rate of 4 percent (World Bank, 2006). Finally, we calculate each country's annual wealth estimate from cropland by multiplying the rental rate per hectare by each country's total annual area of *arable land and permanent cropland* (taken from FAOSTAT).

b) *Agricultural Land: Pastureland*

Pastureland is land on which cattle grazes. Following Munoz et al. (2012), we assume rents per hectare for pastureland to equal those of cropland. This is because the rents per hectare of the former can vary much more than can those of the latter. Therefore, we multiply the rents per hectare for cropland by the total physical amount of pastureland in country i at time t .

Both cropland and pastureland are discounted annually at 4 percent in perpetuity (World Bank, 2011).

c) *Fisheries*

Fishing rents are defined as the difference between total revenues, and total costs and non-fuel subsidies (UNEP, 2011). We refer the reader to Appendix B for further details on calculating fisheries wealth.

d) *Fossil Fuels*

Following Arrow et al. (2012), we calculate production of coal, natural gas, and oil in the years prior to 2012 as follows:

$$K_{t-1} = K_t + \text{production}_t \quad (12)$$

where the stock in year $t-1$ is equal to the sum of the stock and production in year t (e.g. the stock of 2011 is equal to the sum of 2012's stock and production). We do so for two reasons: firstly, as with our commodity term-of-trade (CTOT) index, we are interested in eliminating the Endogeneity effects between quantities and prices. Secondly, historical data on proven reserves taken from the *BP Statistical Review of World Energy* (2013) are unavailable for coal. It is therefore necessary to calculate reserves for coal in this manner; to maintain consistency in our measures, we choose to do the same for oil and gas. We take rents from oil, gas, or coal as a percentage of current GDP [taken from Table 3.15 of the *World Development Indicators* (2013)], and multiply these by GDP in current US\$ (*WDI's* Table 4.1). The WDI uses the same sources to calculate these rents as Arrow et al. (2012) and Muñoz et al. (2012), and are described further in *The Changing Wealth of Nations* (World Bank, 2011). Rents are then expressed in billion cubic feet (natural gas), million tonnes (coal), or 1000 barrels (oil)¹², and multiplied by a country's total available reserves to compute its total wealth from coal, gas, and oil.

Where is the Wealth of Nations?

The World Bank published its “*Where is the Wealth of Nations?*” in 2006. Among many things, the report provides a comprehensive account of the wealth in the year 2000 for almost 120 countries. It also offers a detailed look at the changes in wealth (called *genuine savings*) as a way to measure the sustainable course for these countries since 1970. The report suggests that most developing countries had experienced a drop in both total and natural capital wealth across the 30-year timespan. Table B1 provides a comparison between the World Bank's (2006) wealth estimates and those of our paper. It shows large differences in the shares of natural and human capital. Clearly, the former is much larger across all country groups in this paper, at the expense of the latter. However, the World Bank (2006) excludes countries from its analysis with oil rent shares (as a % of GDP) exceeding 20 percent. In addition, it provides a wealth measure only for the year 2000.

¹² Some production data was expressed in daily values. We multiplied these by 365.

Table B1. Total Wealth^c, including oil states^b (in *percentage* shares)

Income Group	Natural Cap	Physical Cap	Human Cap ^a	Natural Cap	Physical Cap	Human Cap ^a
	WB (2006)	WB (2006)	WB (2006)	Author	Author	Author
1. Low-Income	26%	16%	59%	53%	14%	33%
2. Middle-Income	13%	19%	68%	47%	24%	30%
3. High-Income	2%	17%	80%	28%	19%	53%
4. Overall	4%	18%	78%	40%	21%	40%

Table B2. Total Wealth^c, excluding oil states^b (in *percentage* shares)

1. Low-Income	26%	16%	59%	42%	16%	42%
2. Middle-Income	13%	19%	68%	6%	30%	63%
3. High-Income	2%	17%	80%	16%	20%	65%
4. Overall	4%	18%	78%	19%	21%	60%

^a Human Capital is 'Intangible Capital' in World Bank (2006)

^b Oil states are defined by the World Bank (2006) as countries with an oil-to-GDP ratio exceeding 20%. We define them as countries with an oil-to-wealth ratio exceeding 20%

^c World Bank (2006) estimates based on 120 countries. Author's estimates based on 35 countries.

Table B2 therefore shows estimates when excluding oil states and when only looking at the year 2000. This leads to a drop (rise) in natural (human) capital shares for low-income countries of almost 10 percent. Furthermore, wealth shares are much more in line with those of the World Bank (2006) for middle- and high-income countries. Refer to Figure B (Panel A and B) for a visual on these changes. The remaining differences we attribute to the wider coverage of the World Bank (almost 120 non-oil states), and the difference in methodology for calculating human [see Hamilton (2012) and Liu (2011)] and natural capital [see Arrow et al. (2012) and Muñoz et al. (2012)].

This analysis reveals a potential key difference in the time period between this paper and the World Bank's report; starting from 2003 both oil and non-oil commodity prices have risen to unprecedented highs (see Figure B, Panel C), only to be briefly interrupted by the 2008 financial crisis. Even the World Bank's (2011) update only accounts for wealth up to 2005. Since commodities are included in natural capital, it is no surprise that the (MUV adjusted, i.e. *real*) value of natural capital across the sample has increased by 350% between 2000 and 2011, against a 116% and 62% increase for human and physical capital respectively (see Table C).

Table C
Value of Natural Capital (in *real* billion US\$)

Capital Stock	Year →	2000	2005	2011
Natural Capital		891	2,025	4,001
Physical Capital		307	325	500
Human Capital		942	1,290	2,040

Based on 35 countries

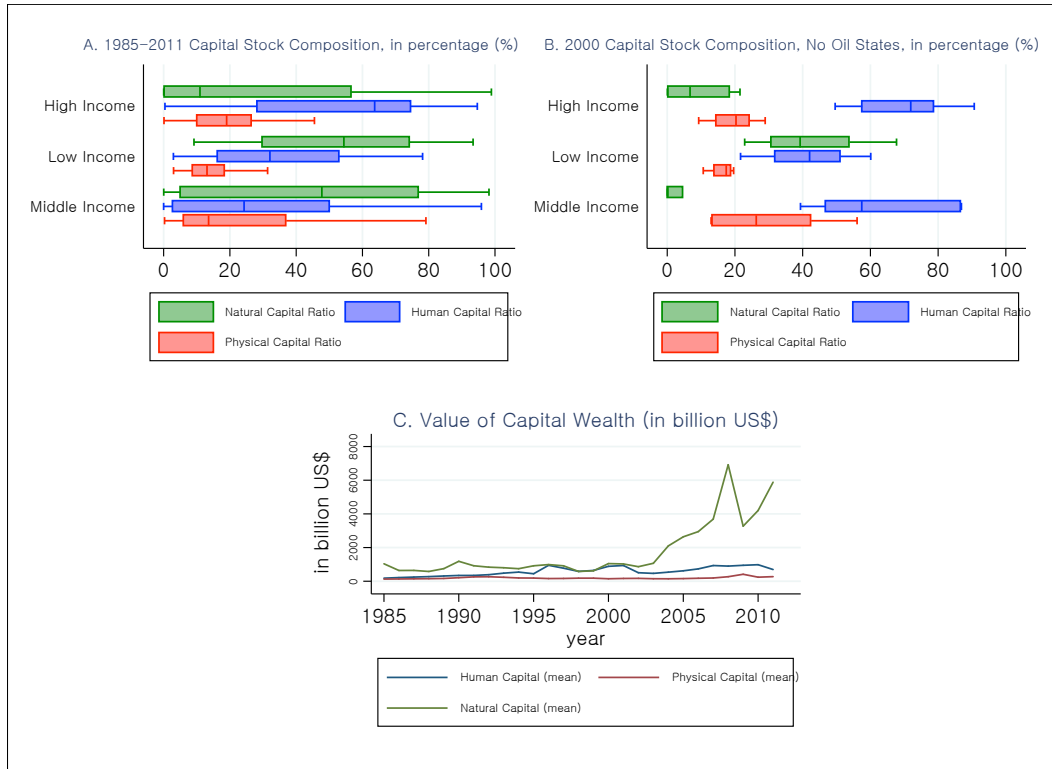


Figure B. (A) and (B) express the shares of natural, physical, and human capital as a ratio of total wealth. (B) excludes oil states (oil-to-wealth ratio >20%) and only shows estimates for the year 2000, as in World Bank (2006). (C) expresses the averages value of natural, human, and physical capital (in *real* billion US\$) for the entire sample. Country groups are classified on their GNI per capita (current US\$; Atlas method; source: WDI). Other source: Author.

The Model: Panel-Vector Auto Regression (Panel VAR)

Following Raddatz (2007; 2009), this paper employs a *panel vector-autoregression* (PVAR) approach to isolate the response of a country's capital stock composition to natural disasters, commodity price fluctuations, and financial aid shocks.¹³ VARs capture the dynamics between variables in a set of equations. In doing so, they make minimal assumptions about the underlying structure of the economy, and instead let the data speak for itself. The main assumptions concern the ordering of the variables and the number of lags to include, both of which we will describe below.

As a starting point, the structural form of our PVAR model for country i is given as follows:

$$A_0 Z_{i,t} = A(L) Z_{i,t-1} + e_{it} \quad (13)$$

¹³ To perform the analysis we rely on the Stata *pvar*-routine written by World Bank senior economist Inessa Love (see Love and Zicchino, 2006)

In this setting, A_0 is an $m \times n$ matrix where the diagonal numbers are 1s, and the non-diagonal numbers are the parameter values that hold the contemporaneous¹⁴ relationship between the variables. Z_{it} is a column-vector (i.e. $m \times 1$) of variables, which are all assumed to be endogenous. This allows basic PVARs to generate forecast profiles between different variables, assuming that a correlation between them exists in the future. It makes PVARs more attractive than traditional structural models, which often have to make assumptions about the exogeneity of variables (BOE, 1999). $A(L)$ is a matrix whose elements are polynomial in lag L , and e_{it} is a vector of error terms capturing unobserved structural disturbances. Following Raddatz (2007), the structural model using our variables of interest is as follows:

$$A_0 Z_{i,t} = \sum_{j=1}^q A_j Z_{i,t-j} + \varepsilon_{it} \quad (14)$$

where

$$Z_{i,t} = (x'_{i,t}, y'_{i,t}), y_{i,t} = (AID_{i,t}, WEALTH_{i,t}), \text{ and}$$

$$x'_{i,t} = (GEO_{i,t}, CLIM_{i,t}, BOOMBUST_{i,t}, OTHER_{i,t})$$

are vectors of endogenous variables (notice the “ ’ ” denoting the weights matrix). We make this distinction, because variables in the first vector are assumed to be more endogenous than those in the second vector. We will elaborate on this in the reduced-form equation specified below. In the first vector, $BOOMBUST_{i,t}$ captures shocks in the commodity terms-of-trade index (CTOT), and $GEO_{i,t}$, $CLIM_{i,t}$ and $OTHER_{i,t}$ embody the occurrence of geological, climatic, and other disasters respectively. The second vector includes $ODA_{i,t}$, i.e. shocks in official development assistant (ODA) as a ratio of gross national income (GNI), and $WEALTH_{i,t}$ as the wealth attributed to either physical, human, or natural capital as a ratio of the total wealth from these three types of capital.

We obtain the reduced-form equivalent of the equation above by multiplying equation (1) by A_0^{-1} :

$$Z_{it} = B(L)Z_{it-1} + u_{it} \quad (15)$$

¹⁴ A ‘contemporaneous’ relationship occurs in the same period of time.

where $B(L) = A_0^{-1}A(L)$ and $u_{it} = A_0^{-1}e_{it}$. In addition, we assume that our PVAR-model is stationary. This requires $E(u_{it}) = 0$. Raddatz (2007) elaborates briefly on an existing debate as to whether macroeconomic variables should be expressed trend stationary or first-difference stationary. The latter type tests for unit roots, and is only powerful enough in settings with large numbers of observations. Panel settings tend to lend themselves well for this situation. We apply the panel unit root test by Levin et al. (2002) and find no unit roots in any of our continuous variables (see table C in Appendix D). We can now specify vector Z with the variables of interest:

$$Z_{it} = (GEO_{it}, CLIM_{it}, BOOMBUST_{it}, OTHER_{it}, ODA_{it}, WEALTH_{it}) \quad (16)$$

Using panel VAR requires us to make a set of assumptions. Our first assumption is to apply an identification strategy usual in PVAR models [see also Love and Zicchino (2006), Raddatz (2007), and Marattin and Salotti (2011)]. This identification strategy states that we impose a so-called *lower triangular Cholesky decomposition*. This is an ordering strategy in which the variables appearing first in the ordering (leftist in vector Z) affect the variables later in the ordering (rightist in vector Z) both contemporaneously and with a lag, while the variables later in the ordering only affect the first variables with a lag. Put differently, geological and climatic disasters are assumed least endogenous [Raddatz (2009) calls them ‘acts of God’]¹⁵. They affect contemporaneously and with a lag commodity terms-of-trade (CTOT) price fluctuations, other disasters, official development assistance (ODA) fluctuations, and our wealth estimates. Some authors have expressed doubts about whether ‘other’ disasters can be grouped in this way, as most (e.g. famines) are at least partly man-made (Noy, 2009). Raddatz (2009) raises the issue as well, but finds no large changes when comparing results including and excluding other disasters. We share Noy’s concern, and therefore make ‘other’ disasters more endogenous than the others [refer to the ordering in equation (16)]. The commodities in the CTOT measures are based on international market prices; therefore, we assume that

¹⁵ Raddatz (2007) actually labels these variables ‘exogenous’. However, the *pvar*-routine used here does not allow us to specify truly exogenous variables. We have been in contact with Simone Salotti from Marattin and Salotti (2011) and with *pvar*-writer Inessa Love, but both clarified that specifying exogenous variables has not been codified yet. We then attempted reaching Claudio Raddatz to request his *pvar*-routine, but have not received a response back yet to date.

no single country can significantly affect them. Nevertheless, they might be affected by natural disasters. AID_{it} is included together with our dependent variable $WEALTH_{it}$ in the $(y'_{i,t})$ -vector of equation (14). They are considered the most endogenous.¹⁶ Raddatz (2007) argues this should be so, because the amount of official development aid (ODA) a developing country receives might depend on both the economic performance of the recipient and the donor. Though we are fairly confident that the chosen ordering is not controversial, we will provide robustness checks with Raddatz' alternative ordering in the results section. We will also provide robustness checks for the initial ordering with alternative lag structures. The lag structure is important to VAR models; too few lags do not properly capture the system's dynamics and can potentially lead to omitted variable bias; too many lags cause an over-parameterisation due to loss in degrees of freedom. Following Raddatz (2007) and Deaton and Miller (1996), our initial model will have three lags, and we will also provide results when restricting the model to one and five lags.¹⁷

Furthermore, panel VAR models assume that the underlying cross-sectional structure is similar across the sample. This is a strong assumption to make, especially since there is no reason to assume similarity between our countries. A common procedure is to remove the *time*-fixed effects by mean differencing the *continuous* (i.e. non-binary) variables, which also removes the constant term in the regressions. However, this procedure creates a bias when using lags. Therefore, in addition to mean-differencing, we follow recent literature¹⁸ and forward-mean difference each continuous variable using the *Helmert*-procedure [see Arellano and Bover (1995) for details]. This transformation procedure removes *state*-fixed effects. By doing so, the Helmert-transformed, demeaned variables remain orthogonal to their lags. This allows us to identify the effect of each individual shock in isolation of the others. Our coefficients are estimated with system Generalized Method-of-Moments (GMM), and we use the untransformed lags as instruments to estimate the Helmert-transformed variables (Love and Zicchino, 2006, Marattin and Salotti, 2011). In the robustness section, we will run a check with first-differenced variables instead of Helmert-transformations.

¹⁶ They are also the only continuous variables. Both are expressed in natural logarithms.

¹⁷ The *pvar*-routine does not allow us to perform lag selection tests ourselves.

¹⁸ Marattin and Salotti (2011) do so in their paper on the effects of government spending on private consumption and investment in the EU.

Results

The Effect of External Shocks on the Wealth of Nations

Following the panel VAR literature [including Raddatz (2007; 2009)], we use impulse response functions (IRFs) to show ten-year forecasts of how wealth (total and individual components) reacts to each shock over time. These IRFs display the effect of ‘orthogonalised’ shocks; i.e. they display the response of one variable to a *one standard deviation* shock in another variable, while keeping all other shocks constant.

Each IRF starts at 0, i.e. the year in which the shock occurs. Each IRF then shows the ten year-ahead forecast error of the response. We define the response in years 0 and 1 as *immediate* or *short-term* effects, in order to account for the fact that some disaster might happen very late in the year. Years 2-10 are the *medium-* and *long-term* effects. The reader can interpret *significance* in the shocks as follows: 5% and 95% confidence bands accompany each of the point estimates in the IRF. Years where *both* bands are above (or both below) the zero-line are years where the wealth measure in question responds significantly (at the 10, 5, or 1 percent level) to an individual shock. We run our PVAR model on a sample of 35 countries over the period 1985-2011.¹⁹ Our sample consists of countries from the following regions; 10 European countries, 14 from Asia, 6 from the Americas, 4 from Africa, and Australia. We were hoping for more countries, as the individual capital stock types each cover at least 50 countries. However, some countries were present in one capital type while absent in another. Future research can hopefully increase this sample accordingly.

Figure 1-7 shows the response of (*log*) total wealth, (*log*) absolute wealth shares, or (*log*) wealth shares as a percentage of total wealth to the occurrence of geological, climatic, and other disasters, price fluctuations in the commodity terms-of-trade (CTOT) index²⁰, and a one standard deviation shock in the (*log*) official development assistance (ODA) as a percentage of GNI. Since occurrences are expressed in binary terms, taking

¹⁹ We initially attempted to cover the 1970-2011 period in order to capture the 1970s and 80s oil crises. It was decided to depart from this focus for now, due to issues in data availability.

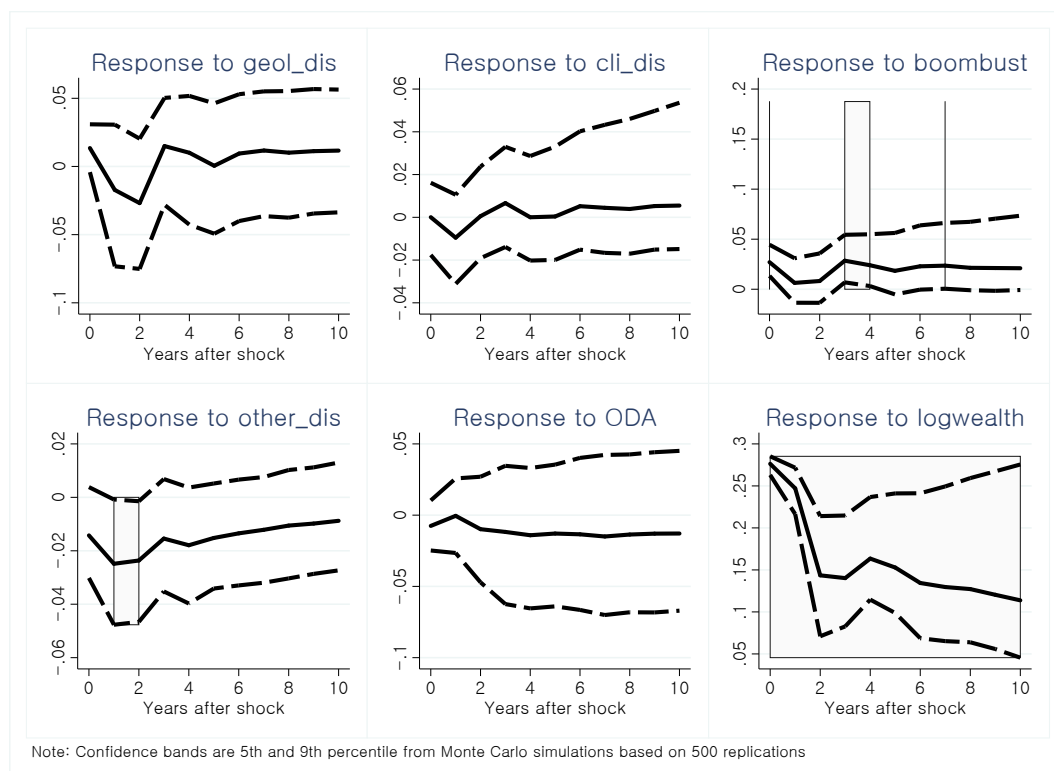
²⁰ A positive shock (boom) or negative shock (bust) takes value 1 if the value of the CTOT index lies farther than 2 standard deviations from the mean. Over-parameterization constraint did not allow us to create separate variables for booms and busts. Attempts were made to include (logged) continuous indices as in Raddatz (2007), but the residuals of these variables were found to be significantly correlated with the other continuous variables.

value one in year 0 and value zero afterwards, and because we use annual data, we assume that they are not serially correlated. Having the capital stock shares expressed in logs creates logged responses. This allows us to interpret them as *percentage changes* as they contain a linear trend (Raddatz, 2007).

We start with Figure 1 to try and find some general responses in wealth as a whole. Commodity price fluctuations have a significant positive effect on the wealth of nations, generating a 2.5% increase in the year of impact, and another positive 2-2.5% increase after the third year. Raddatz (2007) also finds this shock to benefit countries' GDP, but in his paper the effect is only 0.9% after four years. We attribute this difference to our richer measure of wealth, which apart from physical capital also holds comprehensive estimates for human and natural capital. Other disasters (e.g. famines, epidemics, or large accidents) have a significant negative impact after the first year of more than 2%. This is in line with Raddatz (2007). The sixth (bottom-right) panel shows the response of total wealth to its own innovations. It is highly significant at every frequency, which is not surprising. We ignore this sixth panel in each figure throughout the rest of the paper.

Regarding the individual wealth components, the responses by physical capital (Figure 2) are most pronounced; climatic disasters have a small, but very persistent negative effect of almost 2% starting after the second year (the peak). This effect

Figure 1: Response of Wealth (log) to External Shocks



disappears only after the eight year. Though climatic effects have a long onset and are therefore predictable (saving many lives), they are usually able to affect large parts of a country's infrastructure, which is what we believe explains this result and the insignificant result for human capital (Figure 3). Commodity price fluctuations have a positive, cumulative effect on physical capital of about 6% over a seven-year period. Other disasters have significant positive short- and long-term effect on the *ratio* of physical capital in total wealth (Figure 5). We can see this is due to the relatively large decrease in natural capital (Figure 4 and 7), which just falls outside the 10% significance level. Aid shocks affect both physical and human capital significantly, though the former positively in the short-term (1-3%) while the latter negatively in the medium- to long-term (4-8%). The fall in human capital is also shown in its ratio in total wealth (12% in Figure 6).

This result comes as a surprise, as conventional theory finds little evidence of aid provision on poverty and disaster alleviation. Perhaps conventional findings only held when aid is given consistently; however, when aid suddenly falls away, it can have dramatic consequences for a country's population.

Figure 2: Response of Physical Capital (PIM) (log)

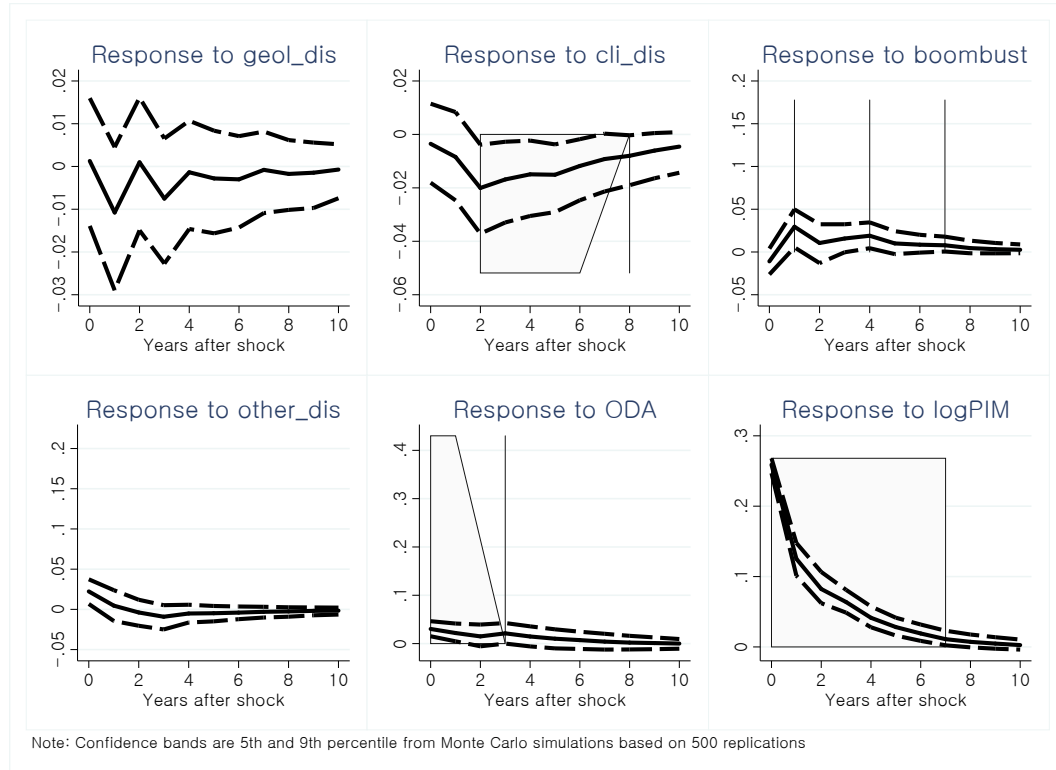


Figure 3: Response of Human Capital (HC) (log)

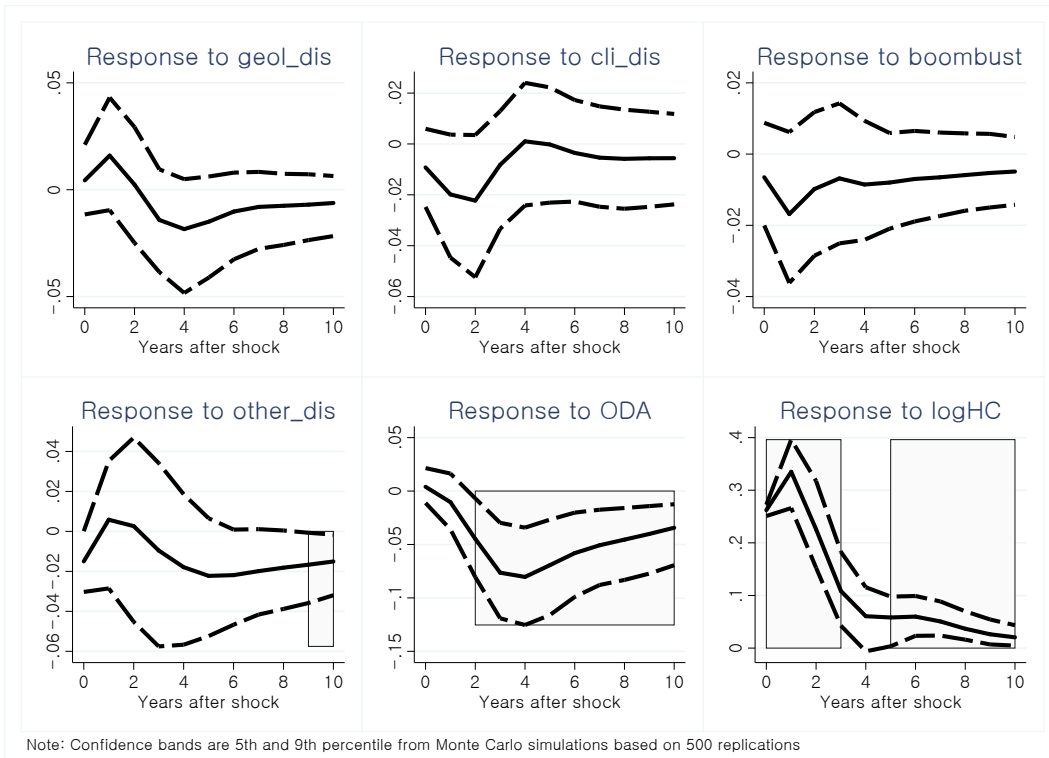


Figure 4: Response of Natural Capital (NC) (log)

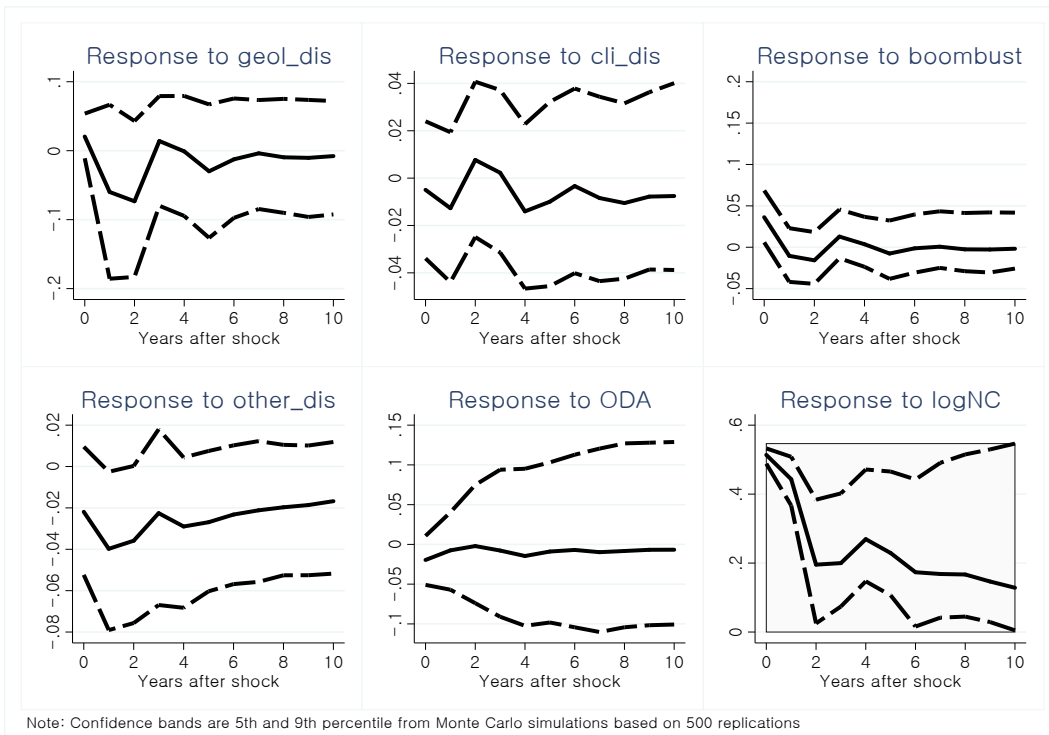


Figure 5: Response of Physical Capital Ratio (PIMr) (log)

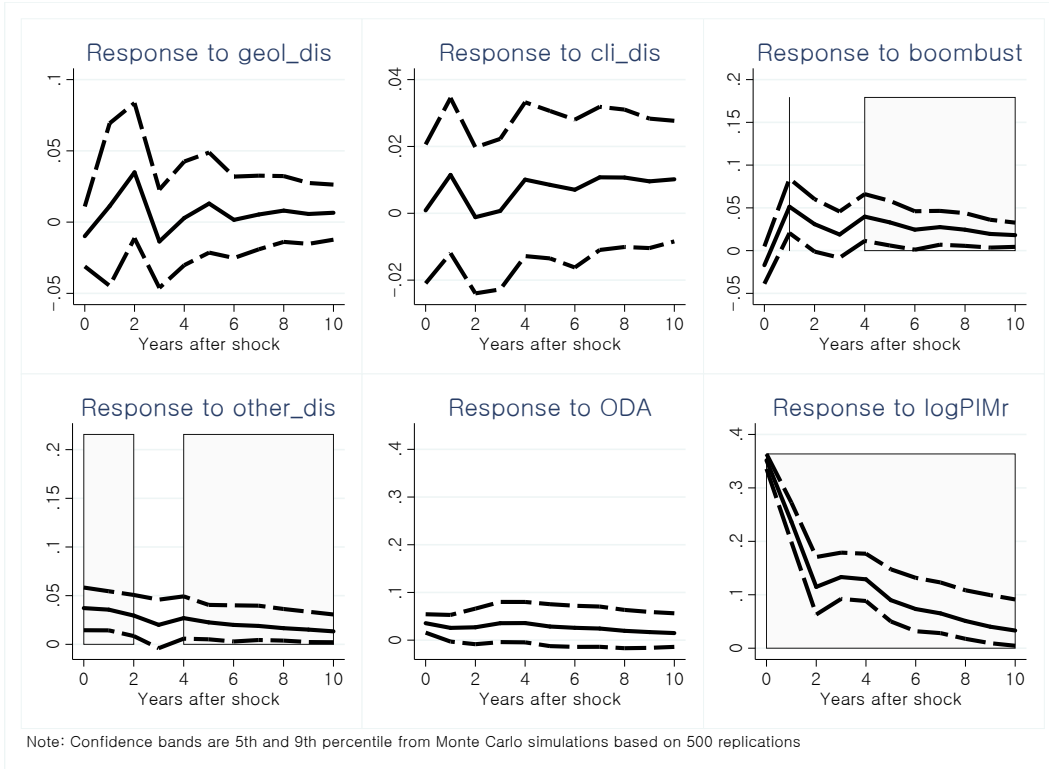


Figure 6: Response of Human Capital Ratio (HCr) (Log)

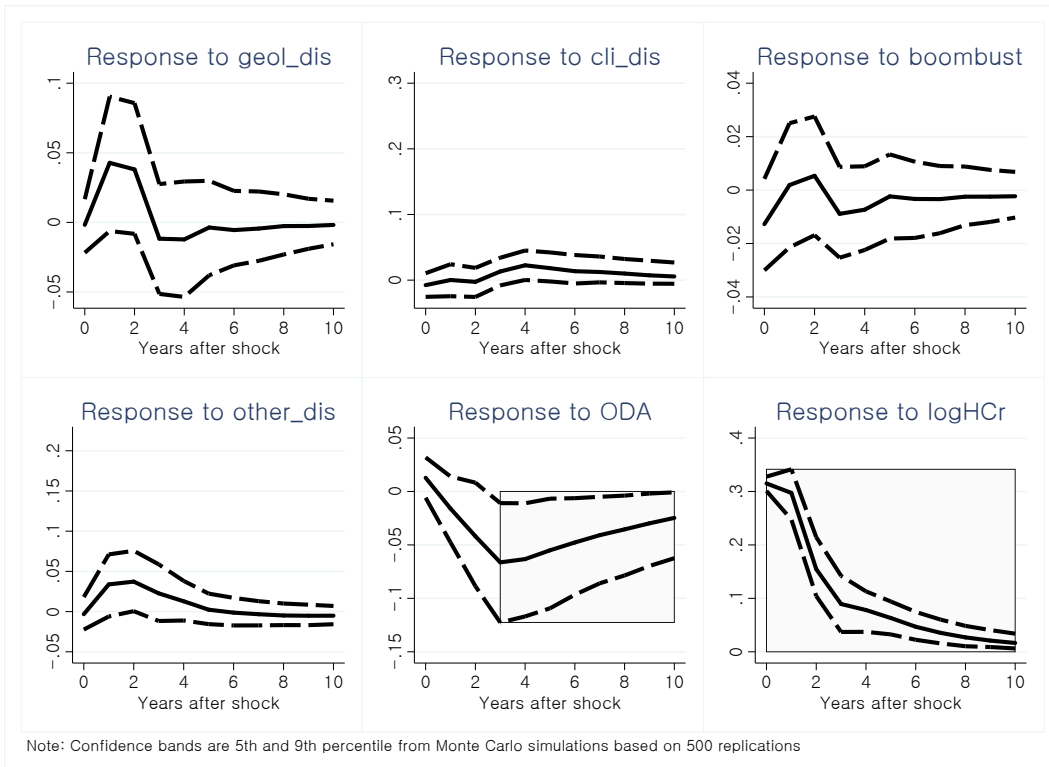
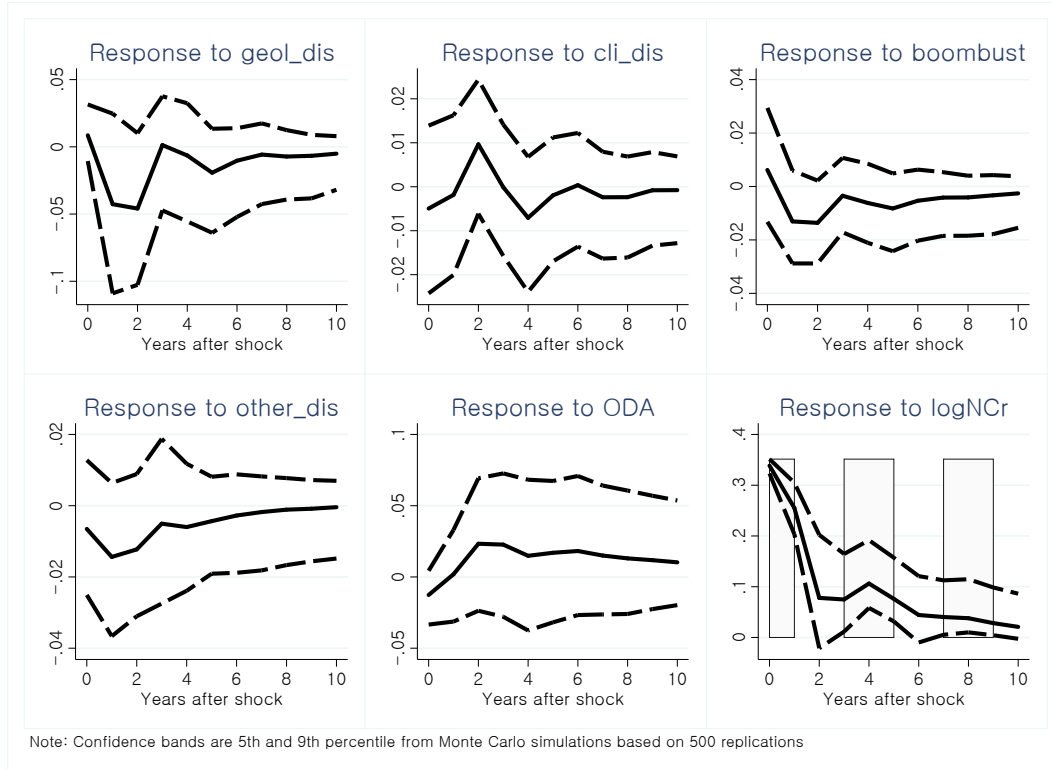


Figure 7: Response of Natural Capital Ratio (HCr) (log)



Can External Shocks Explain Wealth Variations?

Following Raddatz (2007), we look at how much of the variation in our wealth estimates is explained by the external shocks. This is called a ‘standard variance decomposition exercise’, essentially a detailed R-squared table in regular regression outputs. Table D in Appendix D reports on this decomposition.

Column 4-7 presents the fraction of five and ten year-ahead forecast errors that is explained by an external shock. The final column shows the fraction of the variance explained by the dynamics in the response variable itself (mentioned in the first column). This variance captures non-external factors, most likely internal factors (Raddatz, 2007). It appears that external shocks are relatively less important than internal factors. Though this importance increases with forecast horizon, they account for at most 12 percent of variance in our wealth estimates. Therefore, even though external shocks have a statistically significant impact, they are not the main cause for wealth changes. This result is in line with Raddatz (2007), but our results suggest that it holds across a sample with countries in different stages of development. We now look closer at this claim by turning to a series of robustness checks.

Robustness Checks

The results in the previous section were obtained by making assumptions about the ordering of the variables, the variable transformation, and the lag structure. Additionally, results might change when excluding certain periods known to be volatile, or by focusing on countries with unique characteristics. We test the robustness of our initial results in this section by changing assumptions and focusing on a series of subsamples. All IRFs can be found in Appendix C.

a) Alternative Cholesky Orderings, VAR Dimensions, and Lag Structures

Our first robustness check performs an alternative Cholesky ordering, namely to make ‘other’ disasters less endogenous than commodity terms-of-trade (CTOT) price fluctuations, as done in Raddatz (2007). Results virtually do not change anywhere, so we refrain from adding them to this paper. Alternative lag structures also show little sign of change, and are hence excluded as well.

Estimating the model with first differences instead of Helmert-transformations creates responses to a one *variation* instead of a one *standard deviation* shock; responses therefore look sharper and larger in magnitude, but need to be square-rooted to compare (see Figure 8-14). Geological disasters and climatic disasters now have significant positive effects on wealth around the second/third and sixth year (1-2.5% and 1% respectively), and can be attributed to the positive responses of human capital (to climatic disasters) and natural capital (especially to geological disasters). Natural capital increases by more than 3 percent in absolute terms in the third year. As a result, the ratio of physical capital in total wealth experiences a significant decrease due to geological disasters. These results are peculiar, as conventional literature usually finds no large differences between different VAR specifications (Ahmed, 2003, Raddatz, 2007). Running new Levin-Chu tests (not shown) also rule out the presence of unit roots in our first-differenced variables. We can think of two reasons why we get these results: first, other authors usually focus on specific groups of countries and a narrow response measure (GDP), which do not allow for large differences. Second, our estimates show that results are sensitive to model specification, and we therefore advice future research to address more caution to their modelling choice.

b) Alternative Sample Period

We look at whether the 2003-2011-commodity price boom causes the results in our sample to significantly change by excluding these years from the analysis. We ran the

same regressions when excluding the 2008-2011-period (not shown), and found identical results.

By removing the 2003-2011 period, Figure 15-21 show that we have removed most of the significance from the response of wealth to price fluctuations in the commodity terms-of-trade (CTOT). This shows that most of the effect by these price fluctuations can be attributed to the unprecedented surge in both oil and non-oil commodities in the past decade. We interpret this result as evidence for why our natural capital ratio to total wealth was so much higher than that of the World Bank (2006) as shown in Table B. Other responses (e.g. to ‘other’ disasters and aid shocks) stay the same in the short-run, but lose their long-run significance. Since aid shocks were mostly negative in our full sample, this may indicate that aid was given with more certainty in pre-2003. We find evidence for this claim in Raddatz (2007), who finds that commodity price fluctuations lead to a decline in aid flows.

c) Alternative Country Groups

We run a check on all low- and lower middle-income countries as classified by the World Bank, i.e. those with an annual GNI per capita (current US\$, Atlas method) of \$4,085 or less. In addition, we check results for all countries that are located in the geographic tropics to see if geography matters for differences in the wealth of nations. Due to smaller sample sizes, we had to run both checks with only one lag to keep the degrees of freedom in check.

Figure 22-28 refer to the sample of lower income countries. What stands out is the fact that our total wealth measure responds significantly negative to both ‘other’ disasters and aid shock after the first year (1-3% and 3-5% respectively), and that these effects even in the long run do not diminish. Most of these effects can be attributed to the large declines in natural capital (both as a ratio of total wealth and in absolute terms). Raddatz (2007) and Noy (2009) argue that developing countries often do not have the financial means to execute the necessary countercyclical monetary and fiscal policies that developed countries have to their disposal to offset some of the negative effects by these shocks. However, this would not explain why natural capital in particular is hit so adversely. We believe that the larger added value of agriculture and natural resources to total wealth might leave developing countries more vulnerable. Indeed, while the average share of natural capital of non-developing countries is around 30 percent, that share exceeds 50 percent for the developing countries in our sample. Claims over an actual

‘resource curse’ unfolding can at this point not be dismissed, so we encourage future research to incorporate *social capital* (e.g. institutional quality) into the analysis.

Wealth of countries with land area in the tropics (Figure 29-35) responds significantly negative to aid shocks, with a peak of minus 5% after the second year. In addition, the response to ‘other’ disasters is much more persistent; while the response by the entire sample is only significantly negative in the first year, the response by tropical countries persists even after 10 years of the shock. Also in this case, the result is mostly due to the drop in natural capital wealth. Climatic disasters have a significant negative effect after the first year as well of 4%. This result contrasts the positive result Noy (2009) finds, but this author does not specify between types of natural disaster and only looks at damage to property, while we also consider disasters causing considerable deaths and affected people. This again shows that GDP is too narrow a measure to record the full response of shocks; indeed, we find the ratio of physical capital to significantly increase as a result, which is in line with Noy (2009).

Overall, the robustness checks on the functional form of our panel VAR model generally hold, except when first-differencing our continuous variables. Furthermore, specifying subsamples of the data for alternative time periods and country groups show some very interesting results that have not yet been found in previous literature. In particular, the natural capital of lower-income and tropical countries can be significantly damaged by natural disasters and commodity price fluctuations, and we therefore discourage policymakers to ignore natural capital while formulating (countercyclical) macroeconomic policy. Nevertheless, just as with our main specification, we find that most of the variation in the wealth of nations is actually explained by *non-external* factors (Table E, Appendix D).

Concluding Remarks

This paper is the first study to our knowledge that offers a preliminary investigation into the comprehensive wealth effects caused by external shocks. In a panel vector autoregression (PVAR) setting, we find commodity price fluctuations to significantly increase the wealth of nations in our sample, while ‘other’ disasters have a significant negative impact. These effects are robust across several alternative model specifications, except when first-differencing the continuous variables. Future research should therefore take caution when choosing upon a variable transformation. When

excluding the period 2003-2011 from the analysis, the significant positive effect from price fluctuations disappears, implying that the surge in (non-)oil commodity prices in the past decade has had a tremendous impact on nature's part in the world's wealth of nations. We showed that this surge explained much of the wealth estimate differences with the World Bank (2006), and hence encourage more future research into the capital wealth of nations. In addition, lower-income countries and tropical countries are both mostly affected by 'other' disasters (e.g. famines and epidemics) and financial aid shocks. Tropical countries are also negatively affected by climatic disasters. Because all these shocks mostly impact natural capital, we once again stress policymakers to consider their natural treasures when formulating macroeconomic policy.

Some caveats have not been explored here. Most importantly, by considering shocks in isolation, we have not accounted for the possibility that certain shocks occur simultaneously. In addition, we would like to remind the reader that certain shocks are not included in this study, such as (international) interest rates fluctuations, and interactions with possible attenuating variables, such as the quality of institutions [refer to Rodrik (1999), Acemoglu et al. (2003), Raddatz (2006; 2007), and Noy (2009) for non-wealth examples]. Furthermore, the effect of shocks on non-commercial (e.g. subsistence) agricultural productivity might not be captured. Finally, the sample could be vastly expanded by spending a few weeks collecting critical data (e.g., metals and minerals production data from non-digitalized Yearbooks, or forest density per hectare from expert opinions). Time is a student's worst enemy.

References

- ACEMOGLU, D., JOHNSON, S., ROBINSON, J. & THAICHAROEN, Y. 2003. Institutional causes, macroeconomic symptoms: volatility, crises and growth. *Journal of Monetary Economics*, 50, 49-123.
- AHMED, S. 2003. Sources of economic fluctuations in Latin America and implications for choice of exchange rate regimes. *Journal of Development Economics*, 72, 181-202.
- ARELLANO, M. & BOVER, O. 1995. Another look at the instrumental variable estimation of error-components models. *Journal of econometrics*, 68, 29-51.
- ARROW, K. J., DASGUPTA, P., GOULDER, L. H., MUMFORD, K. J. & OLESON, K. 2012. Sustainability and the measurement of wealth. *Environment and Development Economics*, 17, 317-353.

- BALASSA, B. 1981. Policy responses to external shocks in selected Latin-American countries. *Export Diversification and the New Protectionism: The Experience of Latin America*. Bureau of Economic and Business Research, University of Illinois at Urbana-Champaign.
- BARNETT, J. 2003. Security and climate change. *Global Environmental Change*, 13, 7-17.
- BLADES, D. 1997. Depreciation in the National Accounts. OECD.
- BLUEDORN, J. C. 2005. Hurricanes: Intertemporal Trade and Capital Shocks. University of Oxford, Department of Economics.
- BOE 1999. Chapter 5: Vector autoregression models. *Economic Models*. Available at <http://www.bankofengland.co.uk/publications/Documents/other/beqm/1999/five.pdf>. Bank of England.
- BOONE, P. 1996. Politics and the effectiveness of foreign aid. *European Economic Review*, 40, 289-329.
- BP 2013. BP Statistical Review of World Energy. Available at <http://www.bp.com:80/en/global/corporate/about-bp/statistical-review-of-world-energy-2013/statistical-review-1951-2011.html>.
- BRAVO-ORTEGA, C. & DE GREGORIO, J. 2005. The relative richness of the poor? Natural resources, human capital, and economic growth. *Policy Research Working Paper Series*. The World Bank.
- BRUNNSCHWEILER, C. N. 2008. Cursing the Blessings? Natural Resource Abundance, Institutions, and Economic Growth. *World Development*, 36, 399-419.
- BRUNNSCHWEILER, C. N. & BULTE, E. H. 2008. The resource curse revisited and revised: A tale of paradoxes and red herrings. *Journal of Environmental Economics and Management*, 55, 248-264.
- CAVALLO, E. & NOY, I. 2010. The Economics of Natural Disasters. *IDB Working Paper Series No. IDB-WP-124*. Inter-American Development Bank.
- COLLIER, P. Primary commodity dependence and Africa's future. Annual World Bank Conference on Development Economics, 2002. 139-62.
- COLLIER, P. & DEHN, J. 2001. Aid, Shocks, and Growth. *World Bank Policy Research Working Paper*.
- COLLIER, P. & GODERIS, B. 2007. Commodity Prices, Growth, and the Natural Resource Curse: Reconciling a Conundrum. University of Oxford, Department of Economics.

- CRESPO CUARESMA, J., HLOUSKOVA, J. & OBERSTEINER, M. 2008. NATURAL DISASTERS AS CREATIVE DESTRUCTION? EVIDENCE FROM DEVELOPING COUNTRIES. *Economic Inquiry*, 46, 214-226.
- DAWE, D. & TIMMER, C. P. 2012. Why stable food prices are a good thing: Lessons from stabilizing rice prices in Asia. *Global Food Security*, 1, 127-133.
- DEATON, A. & MILLER, R. I. 1995. *International commodity prices, macroeconomic performance, and politics in Sub-Saharan Africa*.
- DEHN, J. 2000. Commodity price uncertainty in developing countries. *World Bank Policy Research Working Paper*.
- DESSUS, S., HERRERA, S. & DE HOYOS, R. 2008. The impact of food inflation on urban poverty and its monetary cost: some back-of-the-envelope calculations. *Agricultural Economics*, 39, 417-429.
- DIETZ, S. & NEUMAYER, E. 2006. A critical appraisal of genuine savings as an indicator of sustainability. *Sustainable development indicators in ecological economics*. Edward Elgar Publishing.
- EASTERLY, W. 2003. Can foreign aid buy growth? *The Journal of Economic Perspectives*, 17, 23-48.
- ECLAC 2003. *Handbook for Estimating the Socio-economic and Environmental Effects of Disasters*, United Nations Economic Commission for Latin America and the Caribbean.
- EM-DAT 2012. The OFDA/CRED International Disaster Database Université Catholique de Louvain, Brussels, Belgium.
- FANKHAUSER, S. & MCDERMOTT, T. forthcoming. Understanding the Adaptation Deficit - Why are poor countries more vulnerable to climate events than rich countries? London School of Economics: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy (CCCEP).
- FAO 2012. Global Capture Production. Available at <http://www.fao.org/fishery/statistics/global-capture-production/en>: Fisheries and Aquaculture Department.
- FAO 2013. FAOSTAT. Available at <http://faostat.fao.org/>.
- FUNKE, N., GRANZIERA, E. & IMAM, P. 2008. Terms of Trade Shocks and Economic Recovery. *IMF Working Papers*. International Monetary Fund.
- GUILLAUMONT, P. & CHAUVET, L. 2001. Aid and performance: a reassessment. *Journal of Development Studies*, 37, 66-92.

- HALLEGATTE, S. & DUMAS, P. 2009. Can natural disasters have positive consequences? Investigating the role of embodied technical change. *Ecological Economics*, 68, 777-786.
- HAMILTON, K. 2012. Comments on Arrow et al., 'Sustainability and the measurement of wealth'. *Environment and Development Economics*, 17, 356-361.
- HAMILTON, K. & LIU, G. 2013. Human capital, tangible wealth, and the intangible capital residual. *World Bank Policy Research Working Paper*.
- HECKMAN, J. J., LOCHNER, L. J. & TODD, P. E. 2003. Fifty years of Mincer earnings regressions. National Bureau of Economic Research.
- IMF 2003. Fund assistance for countries facing exogenous shocks. Policy Development and Review Department. International Monetary Fund.
- IPCC 2007. Climate Change: The Physical Science Basis. Geneva: Intergovernmental Panel on Climate Change.
- IPCC 2012. Summary for Policymakers. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption*. [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.
- IRIN 2005. Disaster reduction and the human cost of disaster. United Nations Integrated Regional Information Networks.
- IVANIC, M. & MARTIN, W. 2008. Implications of higher global food prices for poverty in low-income countries¹. *Agricultural Economics*, 39, 405-416.
- JORGENSEN, D. & FRAUMENI, B. M. 1989. The accumulation of human and nonhuman capital, 1948-84. *The measurement of saving, investment, and wealth*. University of Chicago Press, 1989.
- KAHN, M. E. 2005. The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions. *Review of Economics and Statistics*, 87, 271-284.
- KINDLEBERGER, C. P. & ALIBER, R. Z. 2011. *Manias, panics and crashes: a history of financial crises*, Palgrave Macmillan.
- KING, R. G. & LEVINE, R. 1994. Capital fundamentalism, economic development, and economic growth. The World Bank.
- KING, R. G. & REBELO, S. T. 1999. Chapter 14 Resuscitating real business cycles. In: JOHN, B. T. & MICHAEL, W. (eds.) *Handbook of Macroeconomics*. Elsevier.

- LAFRAMBOISE, N. & LOKO, B. 2012. Natural Disasters: Mitigating Impact, Managing Risks. *IMF Working Papers*. International Monetary Fund.
- LEVIN, A., LIN, C.-F. & JAMES CHU, C.-S. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of econometrics*, 108, 1-24.
- LIU, G. 2011. Measuring the stock of human capital for comparative analysis: an application of the lifetime income approach to selected countries. *OECD Statistics Working Papers*.
- LOVE, I. & ZICCHINO, L. 2006. Financial development and dynamic investment behavior: Evidence from panel VAR. *The Quarterly Review of Economics and Finance*, 46, 190-210.
- MARATTIN, L. & SALOTTI, S. 2011. On the usefulness of government spending in the EU area. *The Journal of Socio-Economics*, 40, 780-795.
- MENDELSON, R., DINAR, A. & WILLIAMS, L. 2006. The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, 11, 159-178.
- MENDOZA, E. G. 1995. The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations. *International Economic Review*, 36, 101-137.
- MUÑOZ, P., DARKEY, E., OLESON, K. & PEARSON, L. 2012. Chapter 2 - Accounting for the Inclusive Wealth of Nations: Empirical Evidence. In: UNU-IHDP and UNEP (2012) Inclusive Wealth Report 2012 - Measuring Progress Toward Sustainability. Cambridge: Cambridge University Press.
- NEUMAYER, E. 2004. National carbon dioxide emissions: geography matters. *Area*, 36, 33-40.
- NORDHAUS, W. D. 2006. Geography and macroeconomics: New data and new findings. *Proceedings of the National Academy of Sciences of the United States of America*, 103, 3510-3517.
- NORDHAUS, W. D. & BOYER, J. 2000. *Warning the World: Economic Models of Global Warming*, MIT Press (MA).
- NOY, I. 2009. The Macroeconomic Consequences of Disasters. *Journal of Development Economics*, 88, 221-231.
- OECD 2012. Aid Statistics. Available at <http://www.oecd.org/dac/stats/odatrendsfrom1960to2012.htm>: Development Co-operation Directorate (DCD-DAC).

- OKRUHLIK, G. 1999. Rentier Wealth, Unruly Law, and the Rise of Opposition: The Political Economy of Oil States. *Comparative Politics*, 31, 295-316.
- OKUYAMA, Y. 2003. Economics of Natural Disasters: A Critical Review. *The 50th North American Meeting, Regional Science Association International*. Philadelphia, Pennsylvania, United States of America.
- PARRY, M. L., ROSENZWEIG, C., IGLESIAS, A., LIVERMORE, M. & FISCHER, G. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14, 53-67.
- PELLING, M., ÖZERDEM, A. & BARAKAT, S. 2002. The Macroeconomic Impact of Disasters. *Progress in Development Studies*, 2, 283-305.
- PORTLAND STATE UNIVERSITY 2012. Country Geography Data. Available at: <http://www.pdx.edu/econ/country-geography-data>.
- PRITCHETT, L. 1996. Population growth, factor accumulation, and productivity. *World Bank Policy Research Working Paper*.
- RADDATZ, C. 2006. Liquidity needs and vulnerability to financial underdevelopment. *Journal of Financial Economics*, 80, 677-722.
- RADDATZ, C. 2007. Are external shocks responsible for the instability of output in low-income countries? *Journal of Development Economics*, 84, 155-187.
- RADDATZ, C. 2009. The Wrath of God: Macroeconomic Costs of Natural Disasters. No. 5039. The World Bank.
- RICARD, D., MINTO, C., JENSEN, O. P. & BAUM, J. K. 2012. Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. *Fish and Fisheries*, 13, 380-398.
- RODRIK, D. 1999. Where did all the growth go? External shocks, social conflict, and growth collapses. *Journal of economic growth*, 4, 385-412.
- ROSSER, A. 2006. *The political economy of the resource curse: A literature survey*, University of Sussex. Institute of Development Studies (IDS).
- SKIDMORE, M. & TOYA, H. 2002. DO NATURAL DISASTERS PROMOTE LONG-RUN GROWTH? *Economic Inquiry*, 40, 664-687.
- SPATAFORA, N. & TYTELL, I. 2009. Commodity Terms of Trade: The History of Booms and Busts. *IMF Working Papers*, 1-34.
- STIGLITZ, J. E., SEN, A. & FITOUSSI, J. P. 2010. Mismeasuring our Lives: Why GDP Doesn't Add Up. New York: The New Press.

- SVENSSON, J. 2000. When is foreign aid policy credible? Aid dependence and conditionality. *Journal of Development Economics*, 61, 61-84.
- UNCTAD 2002. The least developed countries report 2002: escaping the poverty trap.: United States Conference on Trade and Development.
- UNEP 2011. Fisheries - Investing in Natural Capital. Available at http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_3_Fisheries.pdf: United Nations Environment Programme.
- UNESCAP 2013. Building Resilience to Natural Disasters and Major Economic Crises. United Nations Economic and Social Commission for Asia and the Pacific.
- UNSD 2012. National Accounts Main Aggregates Database. Available at <http://unstats.un.org/unsd/snaama/dnList.asp>: United Nations Statistics Division.
- VAN DER PLOEG, F. 2011. Natural resources: Curse or blessing? *Journal of Economic Literature*, 49, 366-420.
- WAVES 2012. Moving Beyond GDP: How to factor natural capital into economic decision making.
- WINTERS, L. A. 2002. Trade Liberalisation and Poverty: What are the Links? *World Economy*, 25, 1339-1367.
- WORLD BANK, T. 2006. Where is the Wealth of Nations? Washington, DC: World Bank.
- WORLD BANK, T. 2011. The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium. Washington, DC. Available at <http://data.worldbank.org/data-catalog/wealth-of-nations>: World Bank.
- WORLD BANK, T. 2012. *Wealth Accounting and Valuation of Ecosystem Services (WAVES)*. Available at: <http://www.worldbank.org/programs/waves> [Online].
- WORLD BANK, T. 2013. World Development Indicators. Available at <http://wdi.worldbank.org/table>.
- WORLD BANK/FAO, T. 2009. The Sunken Billions: The Economic Justification for Fisheries Reform. Washington D.C., Rome: World Bank and Food and Agriculture Organization.
- WORLDBANK 2012. World Development Indicators. In: STATISTICS, U. I. F. (ed.). Available at <http://data.worldbank.org/indicator>.
- WRIGHT, B. D. 2011. The Economics of Grain Price Volatility. *Applied Economic Perspectives and Policy*, 33, 32-58.

YANG, D. 2006. Coping with Disaster: The Impact of Hurricanes on International Financial Flows, 1970-2002. National Bureau of Economic Research, Inc.

Appendices

A. Data Sources

Data on commodity prices are taken from the IMF *Primary Commodity Prices* database. Export and import data on individual commodities are from the United Nations' COMTRADE database, and GDP from the World Bank's *World Development Indicators* and the IMF's *World Economic Outlook*. The latter also holds the MUV data. Please refer to Spatafora and Tytell (2009) for more details on the data collection process.²¹

Official development aid (ODA) data is taken from the *Development Co-operation Directorate* by the OECD (2012), and GDI data from the World Bank's *World Development Indicators* (WDI).

Gross capital formation (i.e. gross investment-to-output) and GDP growth rates are taken from the *National Accounts* of the UNSD (2012). We multiply this measure by constant GDP data from the World Development Indicators to acquire annual investments.

Finally, data on the percentage of land area in the geographical tropics used in the Tropics robustness check are taken from the *Country Geographical Data* by Portland State University (2012).

B. Fisheries Wealth

While current estimates of annual global fisheries rents are found to be actually negative (minus US\$5-26 billion), reports by UNEP and the World Bank/FAO estimate annual rents would be around US\$45 billion when all fish would be caught at its Maximum Sustainable Yield (MSY), a difference of at least US\$50 billion per year (World Bank/FAO, 2009, UNEP, 2011). Earlier studies find even larger differences of US\$46-90 billion (see table 4.2 in World Bank/FAO, 2009). Several reports and textbooks

²¹ There were issues obtaining some of the commodity price data prior to 1988. Fortunately, I was able to obtain all the necessary raw data from Dr. Nikola Spatafora for 1985-2011, for which I am very grateful. Any gaps in the data were not imputed.

attribute this to the industry's poor state of management; most commercial fishing areas are open-access, where fishermen are unable to prevent competitors from depleting the stock of fish. This *tragedy of the commons* results in negative resource rents, and most industries are hence kept alive artificially by hefty subsidies (World Bank/FAO, 2009).

These differences make it extremely challenging to calculate appropriate rents for the purpose of this paper. We decide to assume the annual rents of US\$50 billion. This estimate is from 2009, so we express it in real terms across the sample by deflating it using the MUV. We then divide this by annual *Global Capture Production* [taken from the FAO (2012)] to acquire the rents per tonne. Rents per tonne are then multiplied by the *Spawning Stock Biomass* from the *RAM Legacy Stock Assessment Database* (Ricard et al., 2012) to form total wealth from fisheries. Unfortunately for this analysis, there are only 8 countries in the world that have fish stocks specifically attributed to their territory; the rest resides in regional or international waters that are not easily attributed to individual countries.²²

C. Figures

Note: 'geol_dis' is geological disaster; 'cli_dis' is climatic disaster; 'boombust' is a positive (boom) or negative (bust) shock in the commodity terms-of-trade index (CTOT); 'other_dis' is other disaster; 'ODA' is a shock in official development assistance (ODA). Refer to the name in the title of each figure for the abbreviation in the bottom right panel, which reflects the dynamics of the response variable to its own innovation. Solid lines reflect point estimates of response variable to each external shock. Dotted lines reflect the 5% and 95% confidence bands. Shaded areas in each panel reflect statistically significant responses by the response variable in that year.

Each figure reports the impulse response functions (IRFs) of the response variable (in the title) to external shocks and its own innovation. IRFs are estimated with a panel VAR model.

²² These countries are Argentina, Australia, Canada, Iran, New Zealand, Peru, South Africa, and the USA. Future research could perhaps attempt to distribute spawning stock biomass to countries located in regions identified as 'multinational'.

Figure 8: First-Difference Response of Wealth (log)

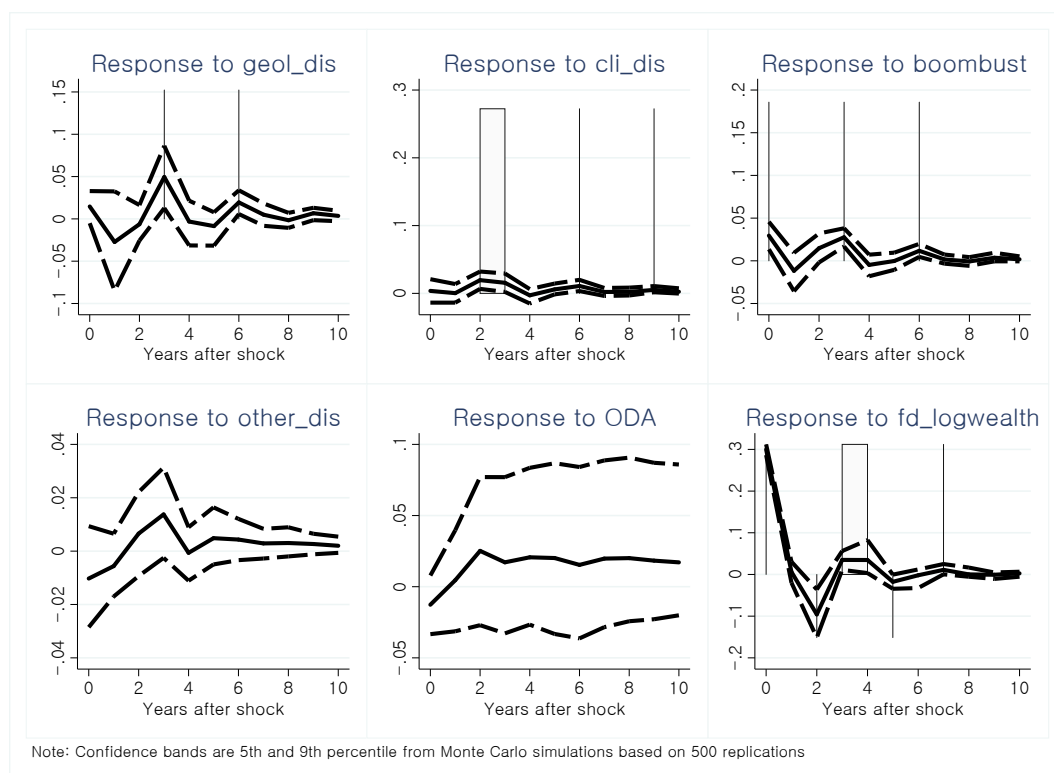


Figure 9: First-Difference Response of Physical Capital (log)

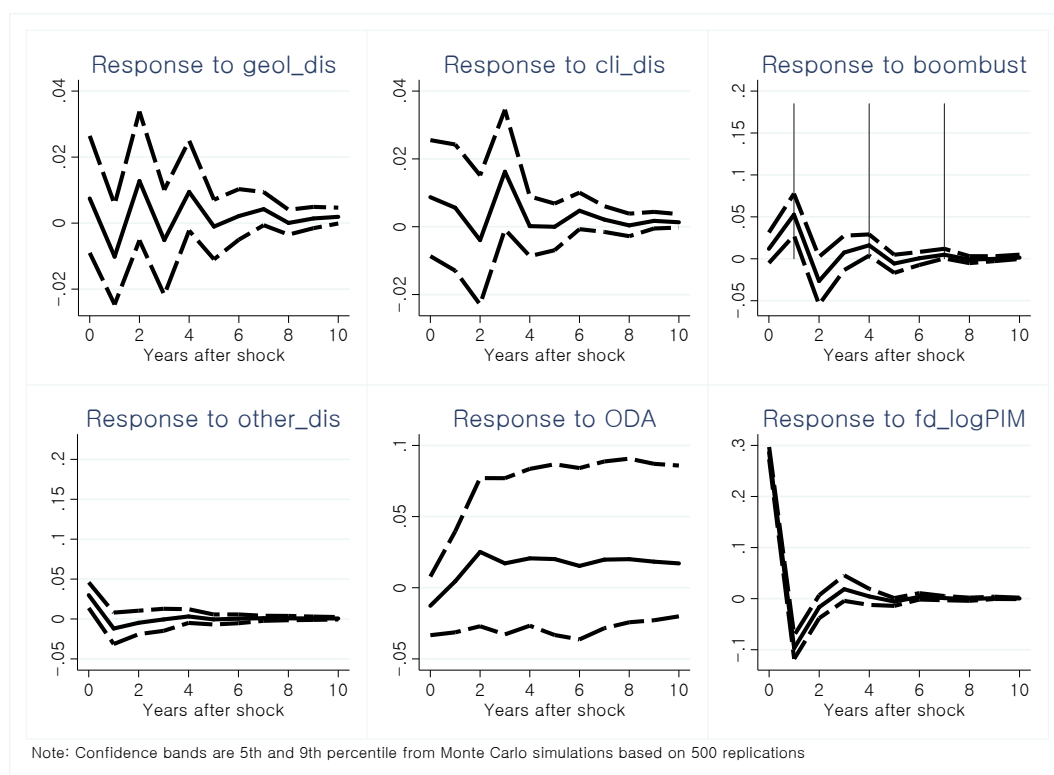


Figure 10: First-Difference Response of Human Capital (log)

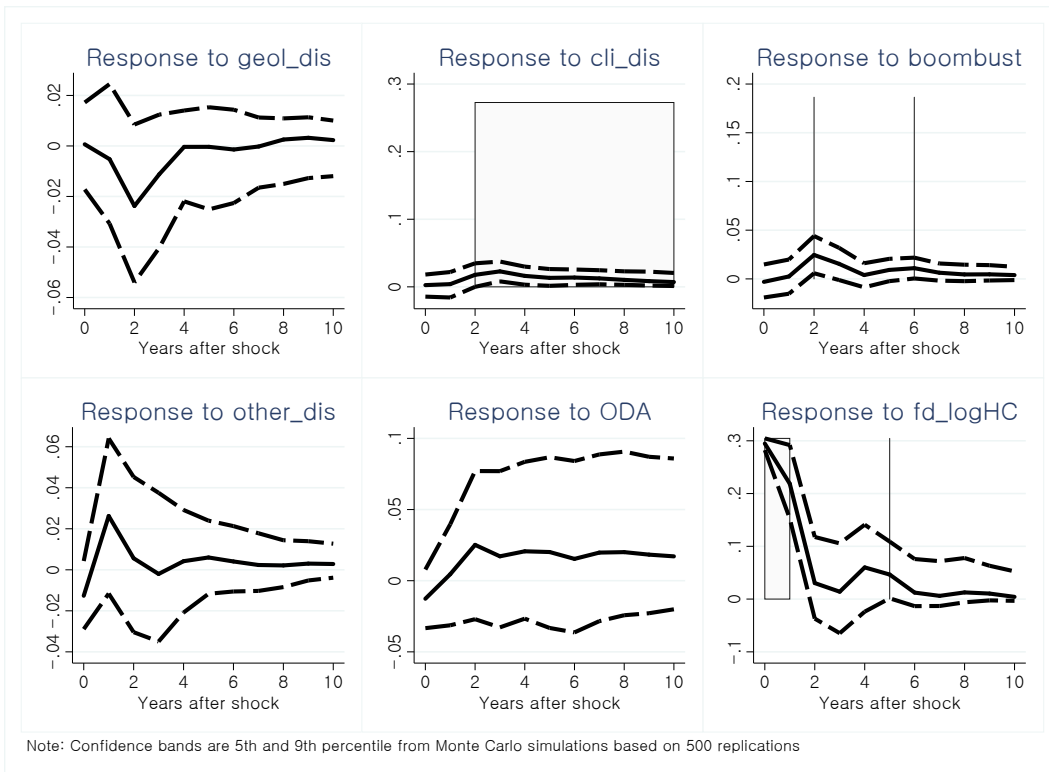


Figure 11: First-Difference Response to Natural Capital (log)

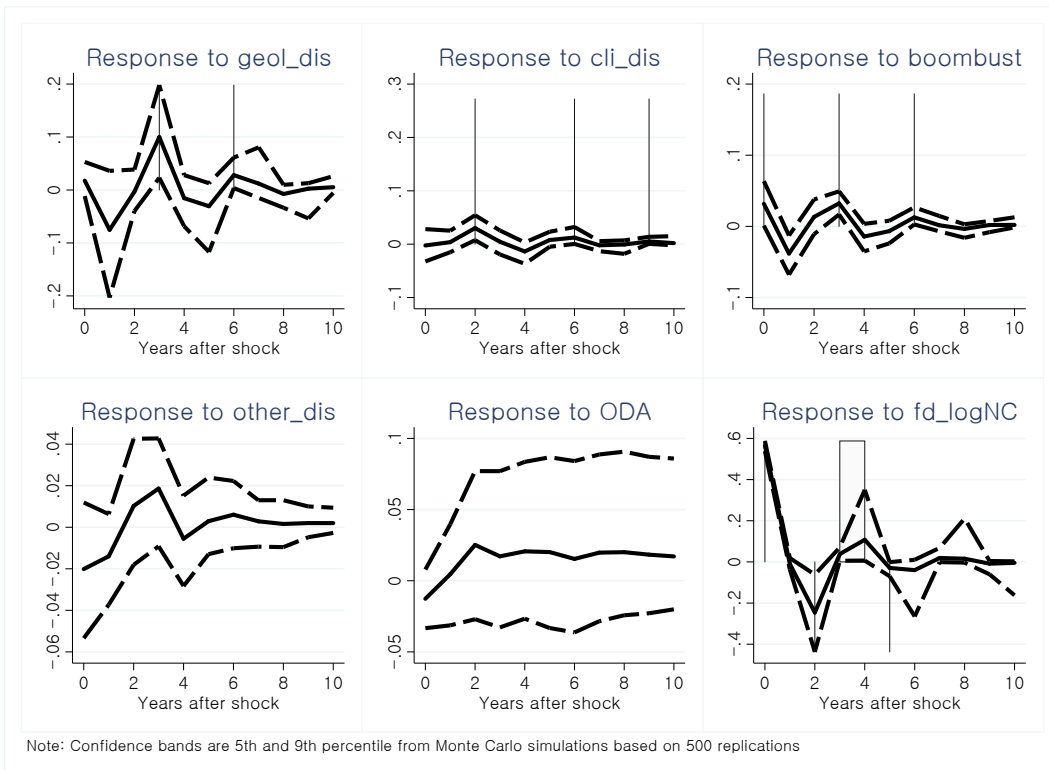


Figure 12: First-Difference Response to Physical Capital Ratio (log)

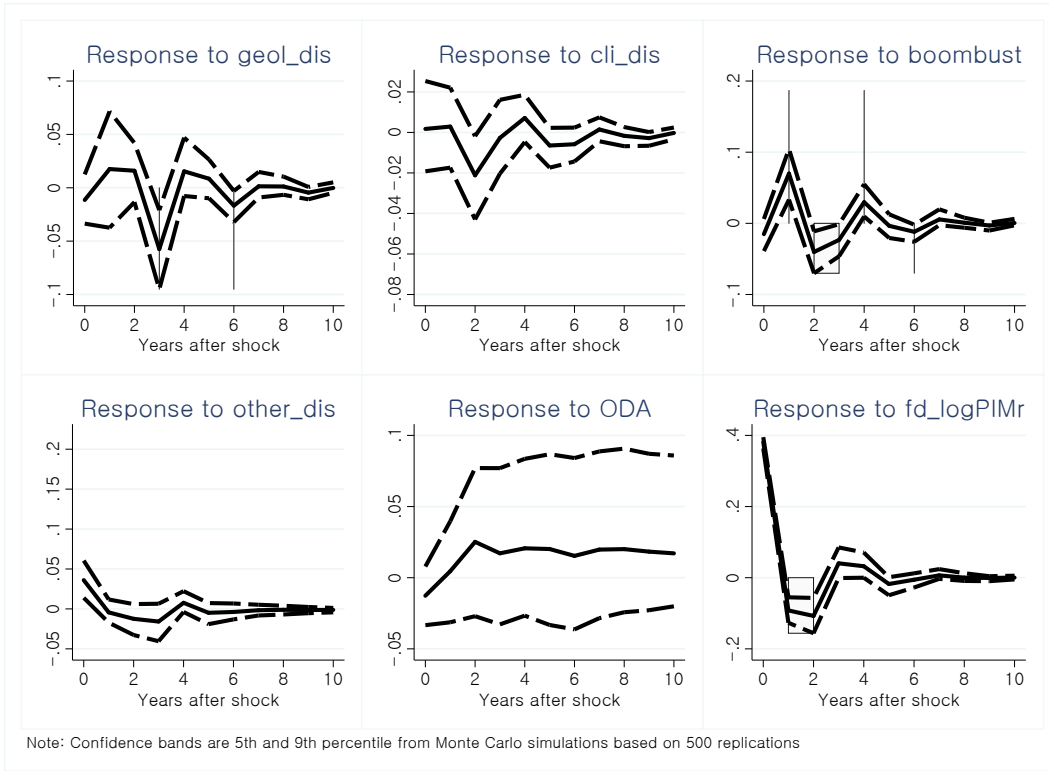


Figure 13: First-Difference Response to Human Capital Ratio (log)

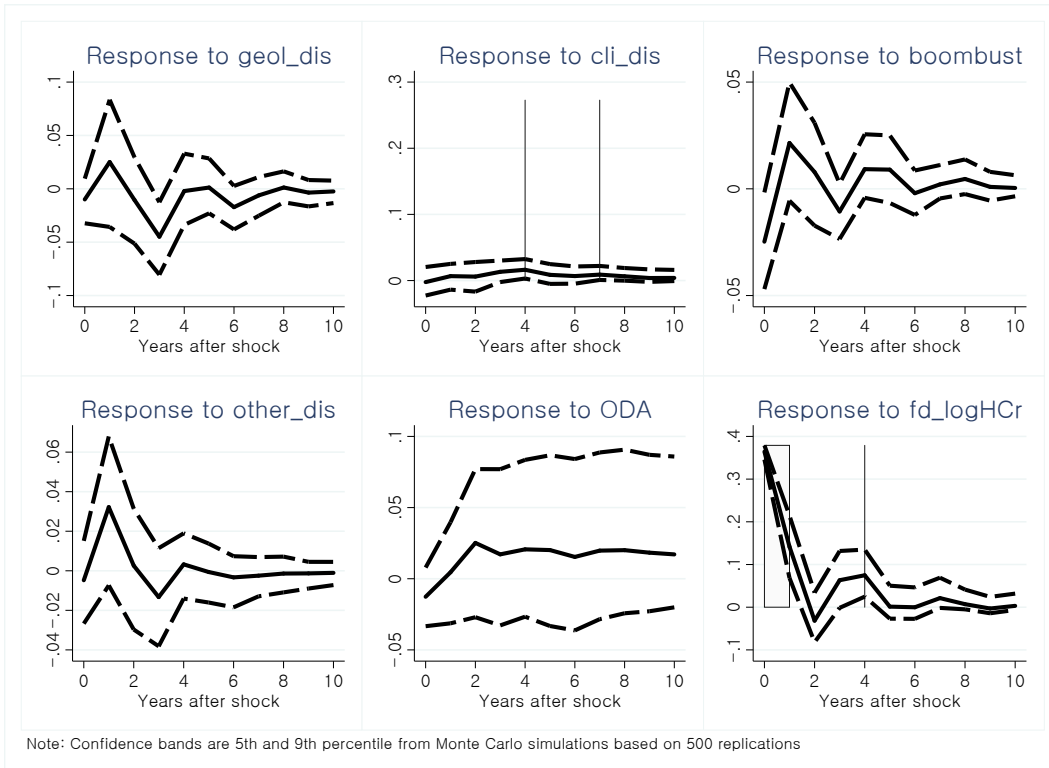


Figure 14: First-Difference Response to Natural Capital Ratio (log)

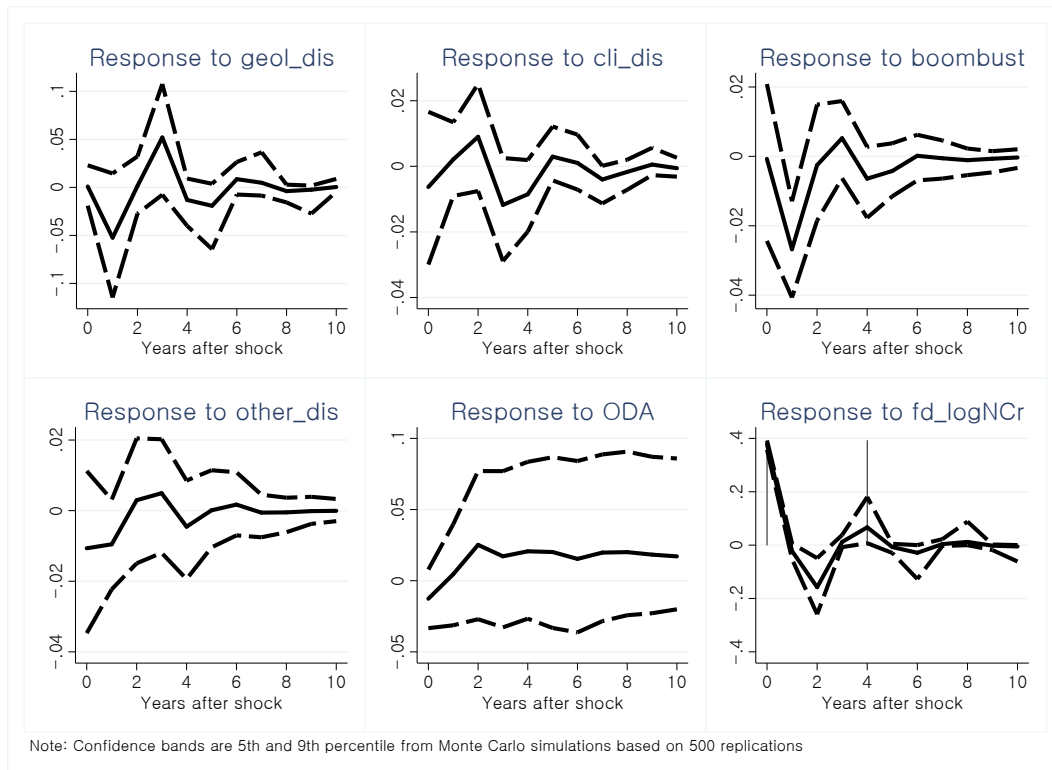


Figure 15: 1985-2002 Response of Wealth (log) to External Shocks

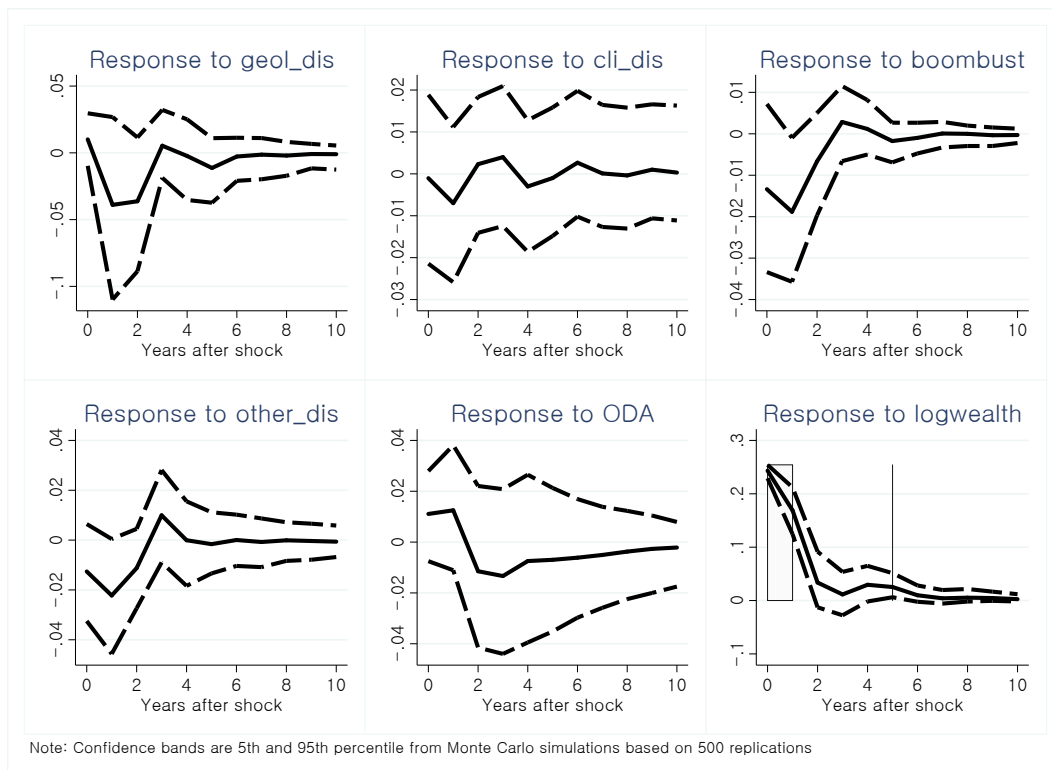


Figure 16: 1985-2002 Response of Physical Capital (log) to External Shocks

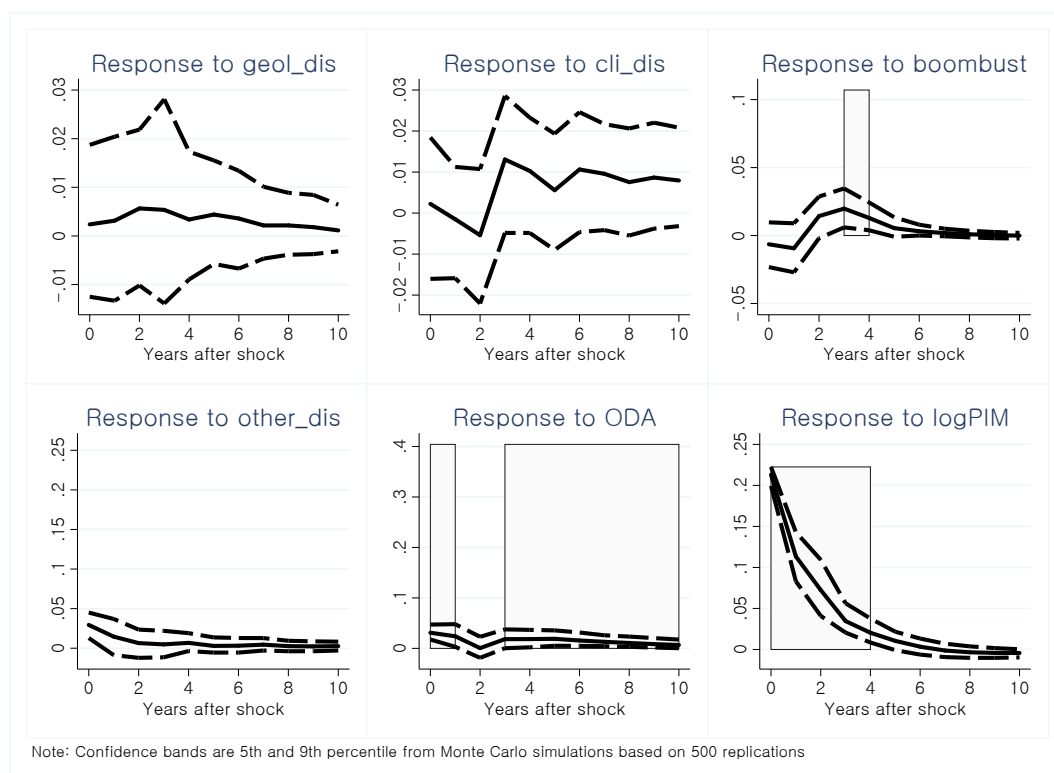


Figure 17: 1985-2002 Response of Human Capital (log) to External Shocks

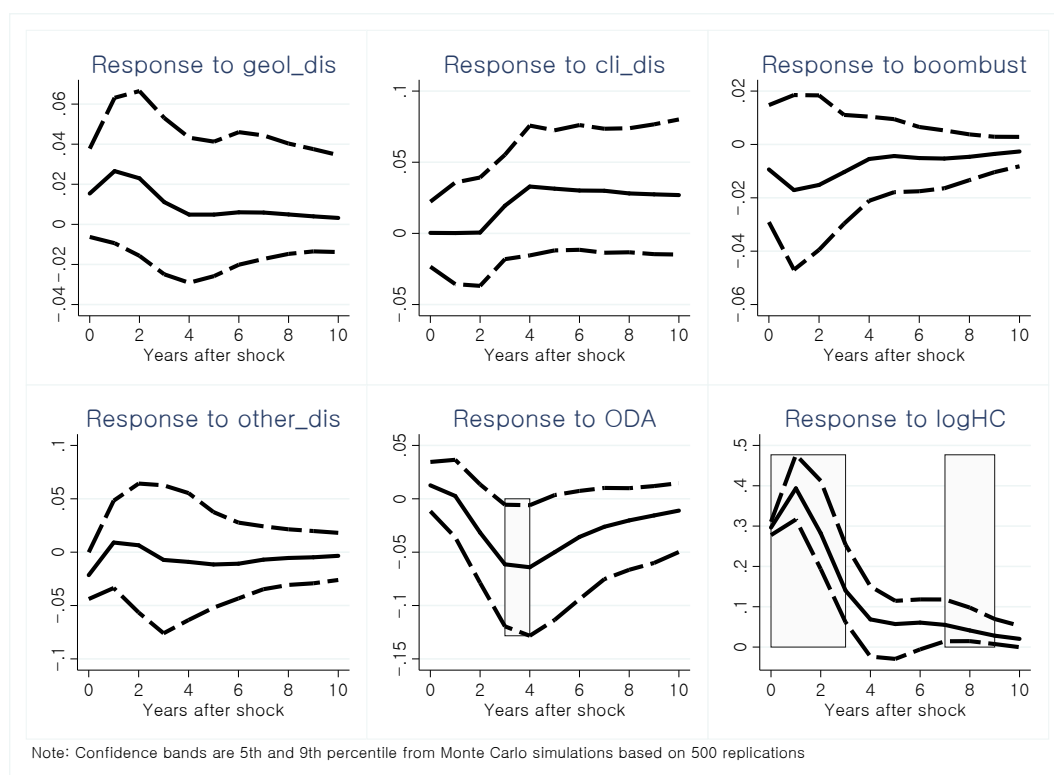


Figure 18: 1985-2002 Response of Natural Capital (log) to External Shocks

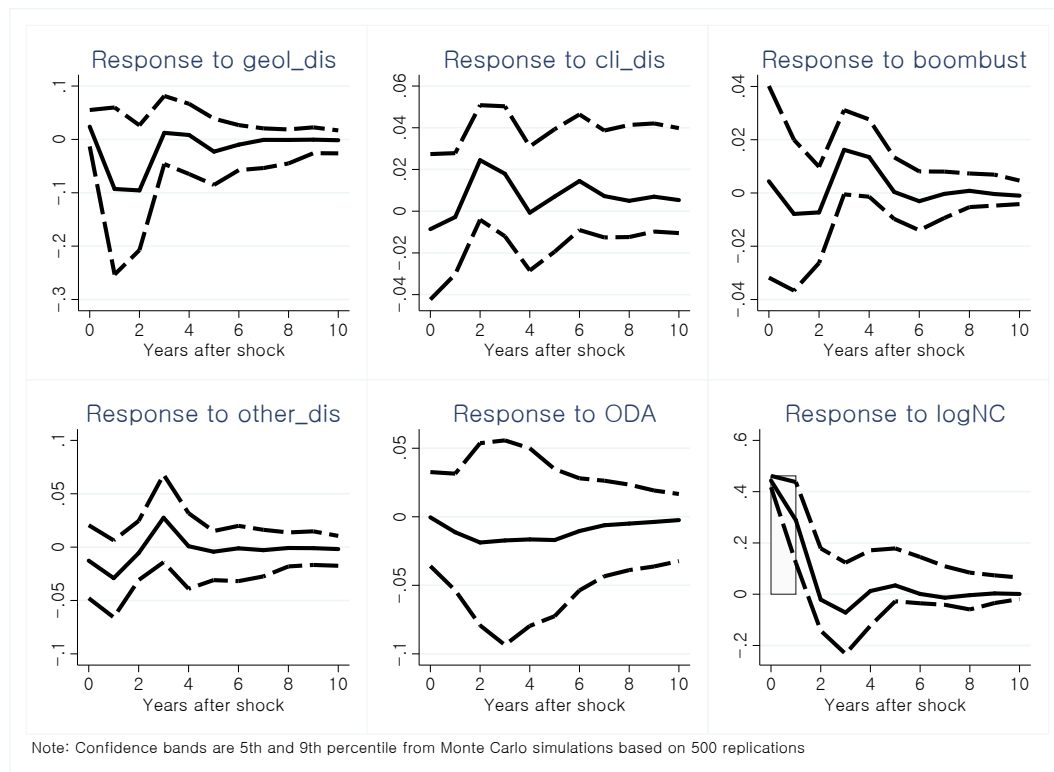


Figure 19: 1985-2002 Response of Physical Capital Ratio (log) to External Shocks

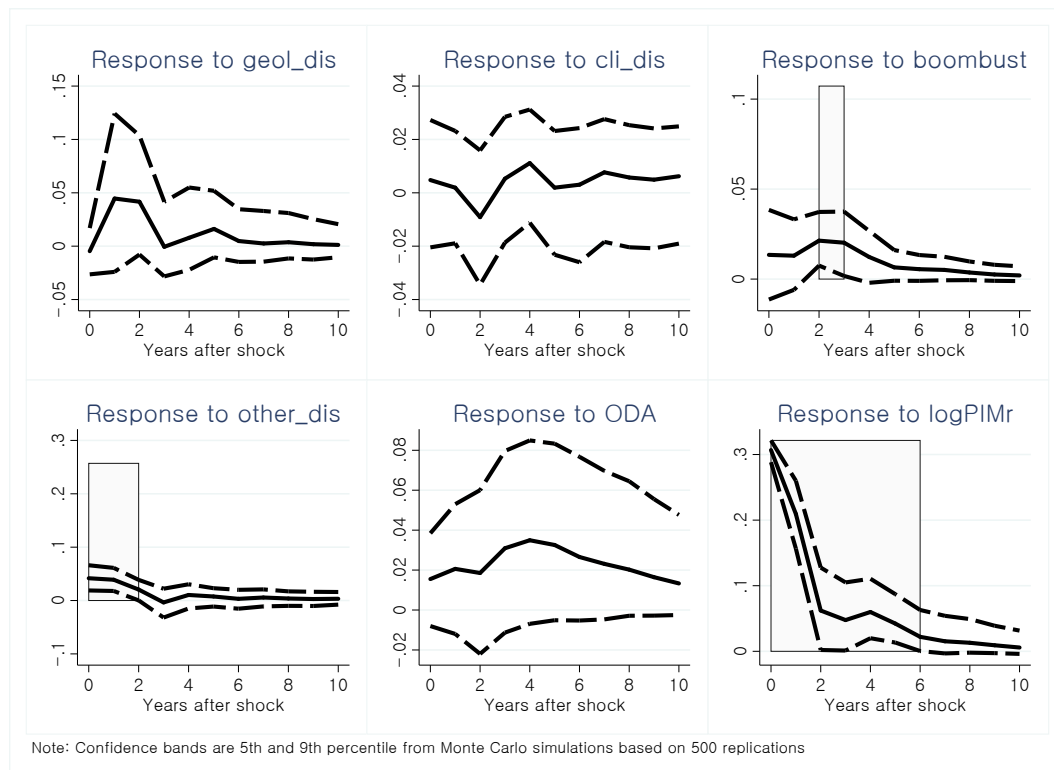


Figure 20: 1985-2002 Response of Human Capital Ratio (log) to External Shocks

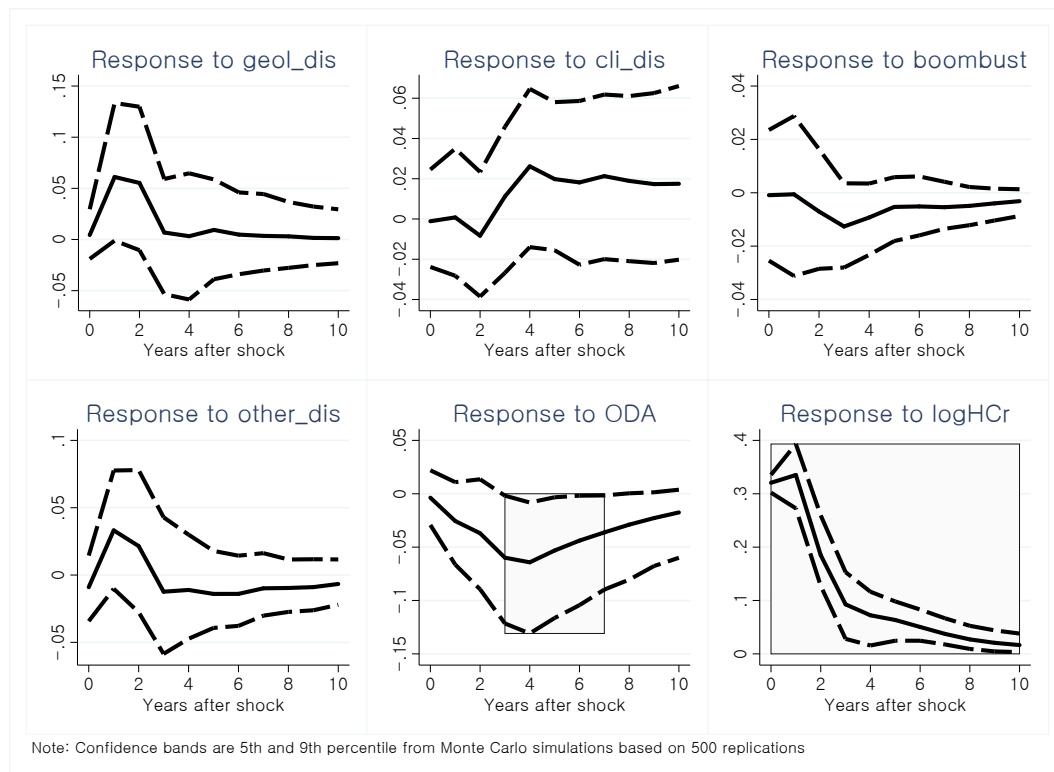


Figure 21: 1985-2002 Response of Natural Capital Ratio (log) to External Shocks

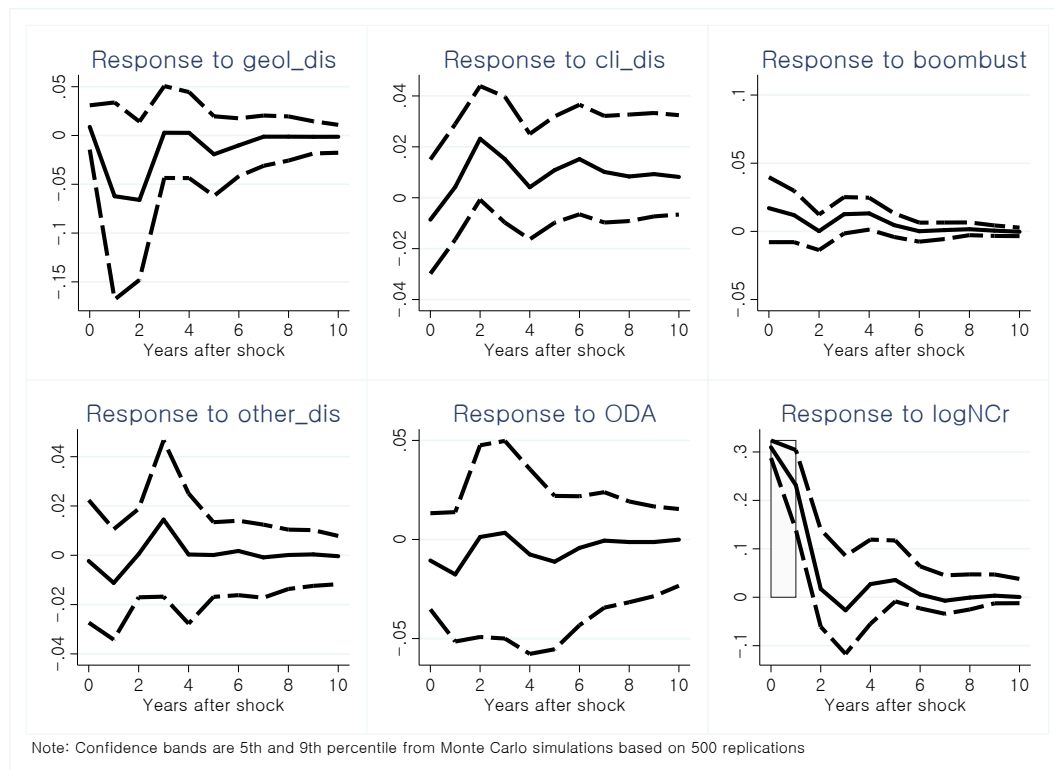


Figure 22: Responses of Lower-Income Country Wealth (log)

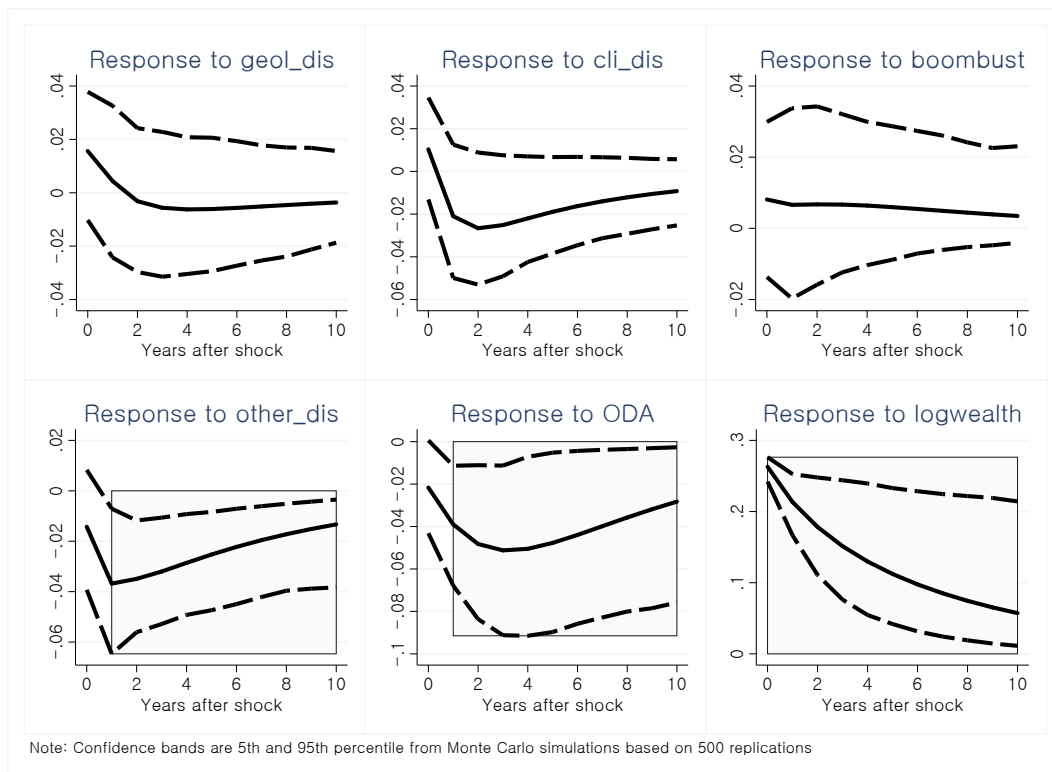


Figure 23: Responses of Lower-Income Country Physical Capital (log)

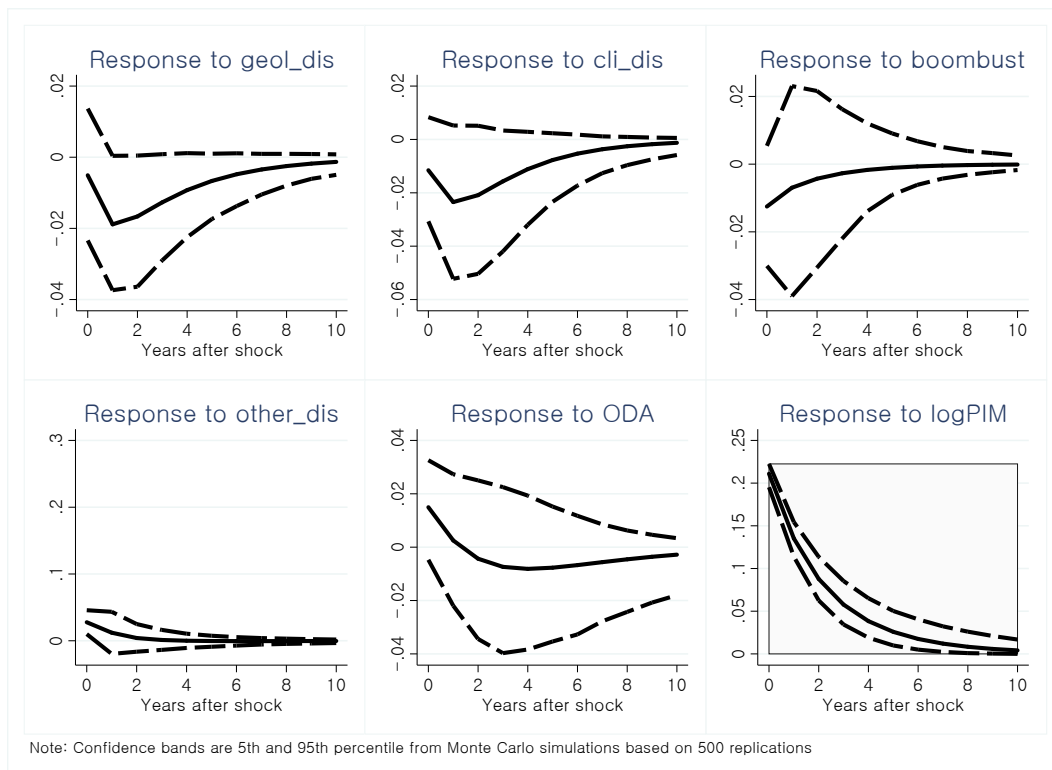


Figure 24: Responses of Lower-Income Country Human Capital (log)

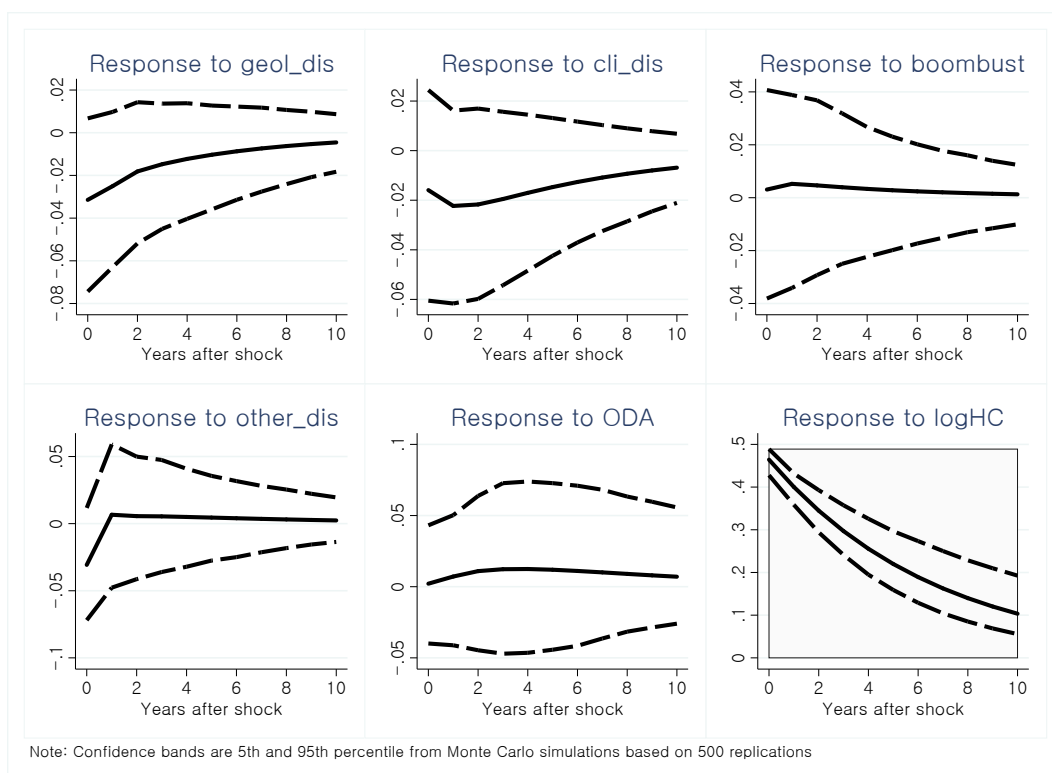


Figure 25: Responses of Lower-Income Country Natural Capital (log)

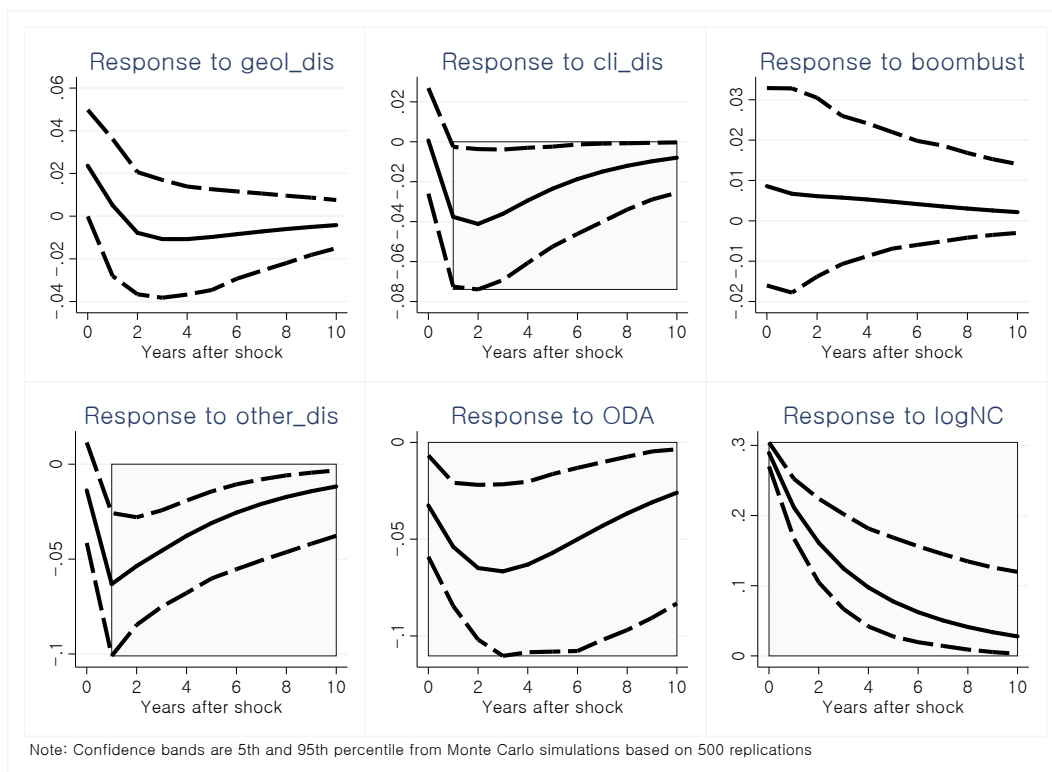


Figure 26: Responses of Lower-Income Country Physical Capital Ratio (log)

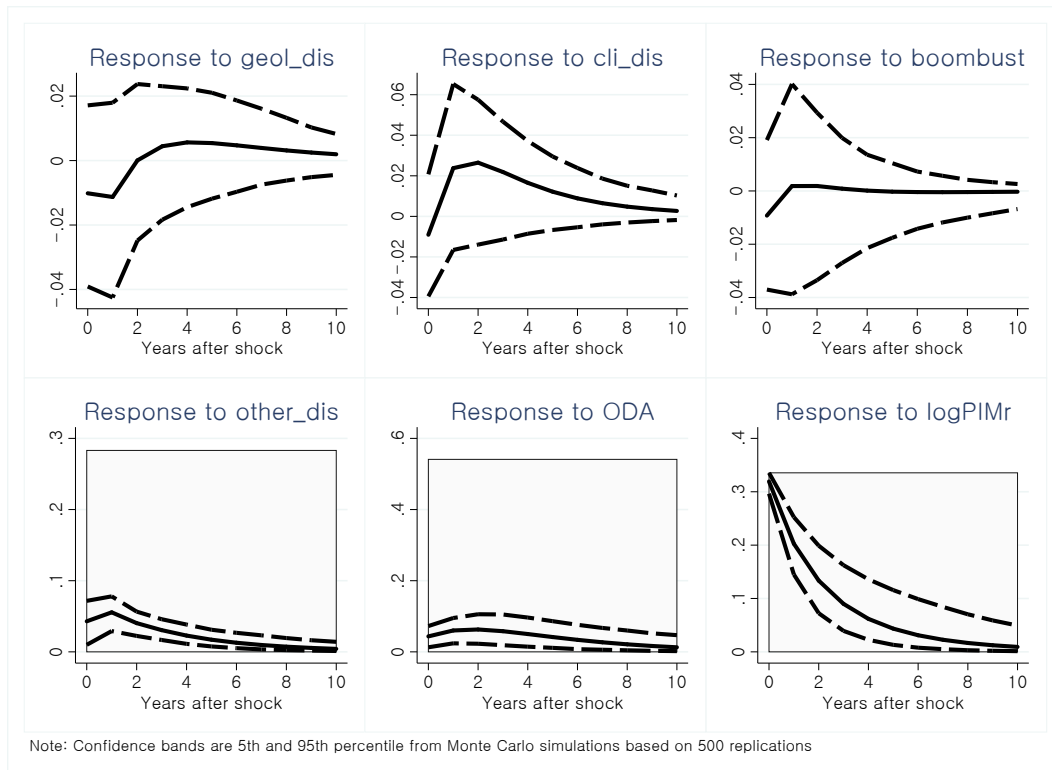


Figure 27: Responses of Lower-Income Country Human Capital Ratio (log)

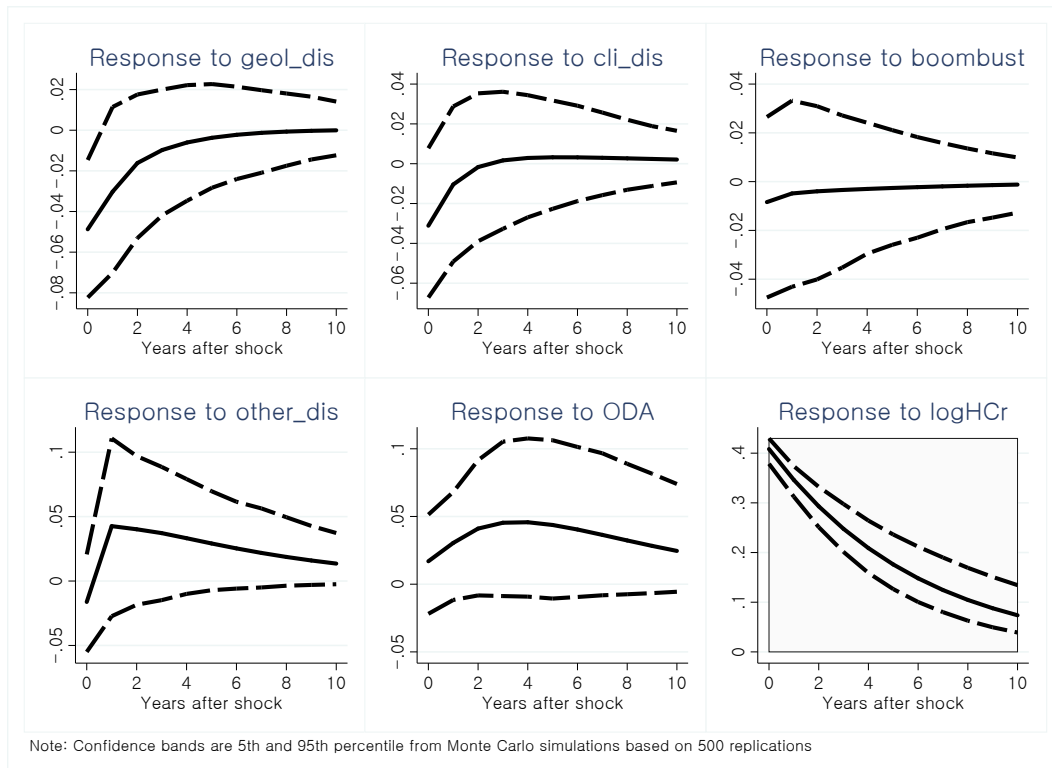


Figure 28: Responses of Lower-Income Country Natural Capital *Ratio* (log)

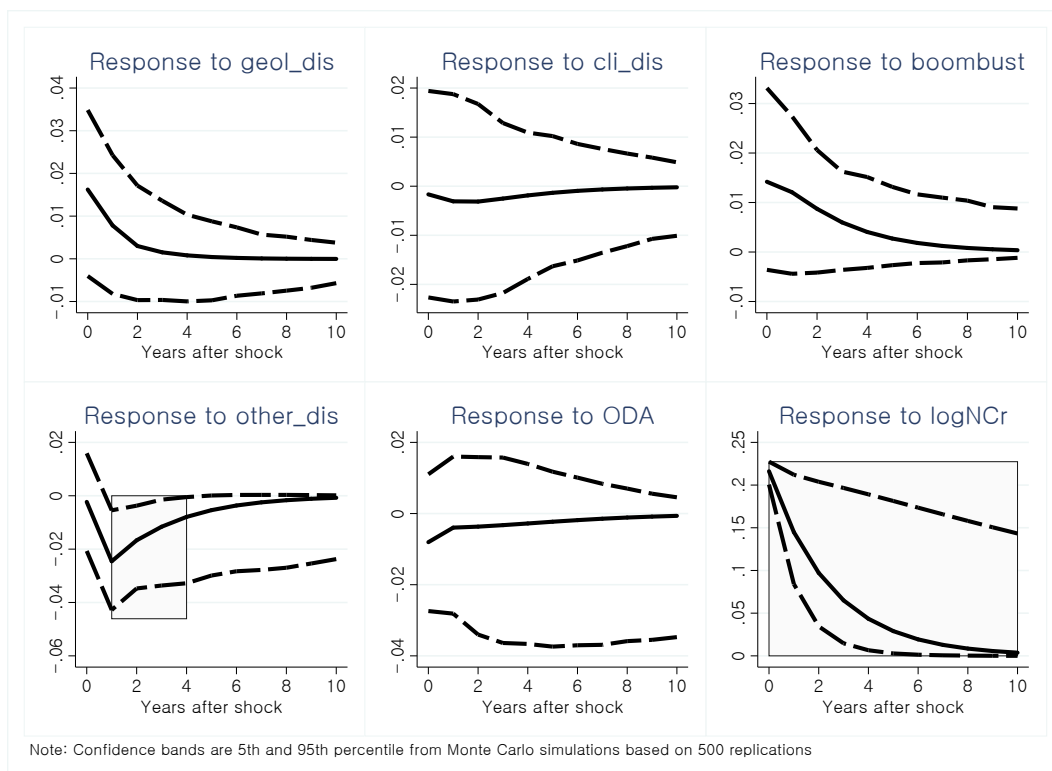


Figure 29: Response of Tropical Country Wealth (log)

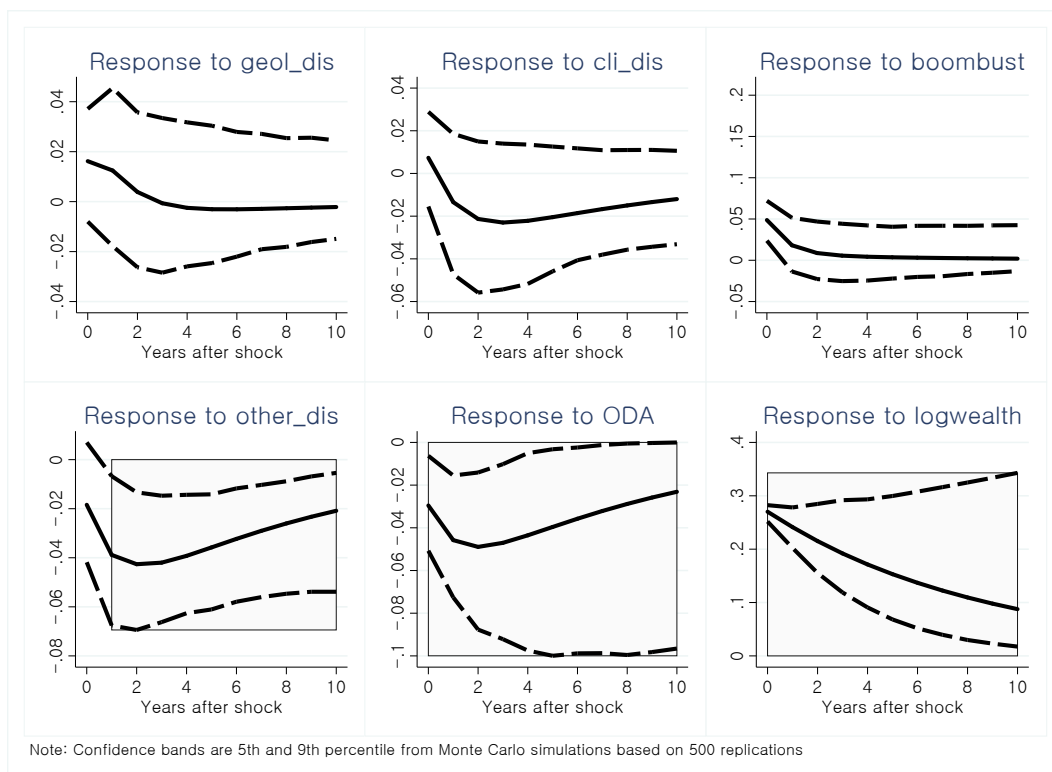


Figure 30: Response of Tropical Country Physical Capital (log)

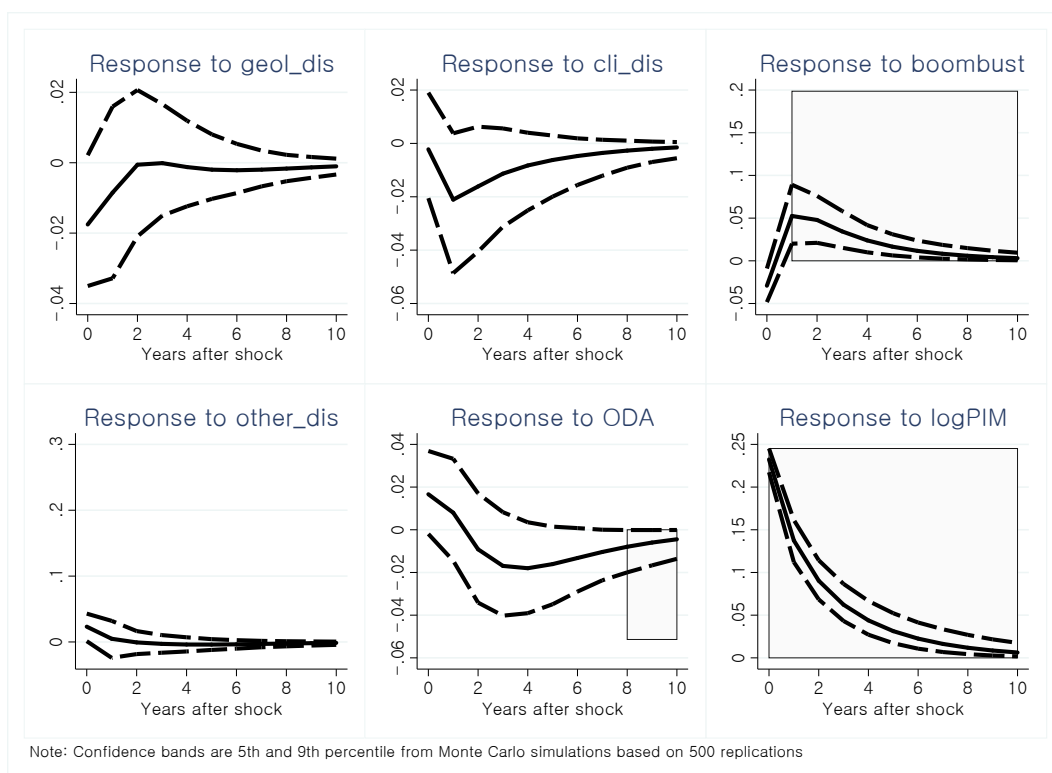


Figure 31: Response of Tropical Country Human Capital (log)

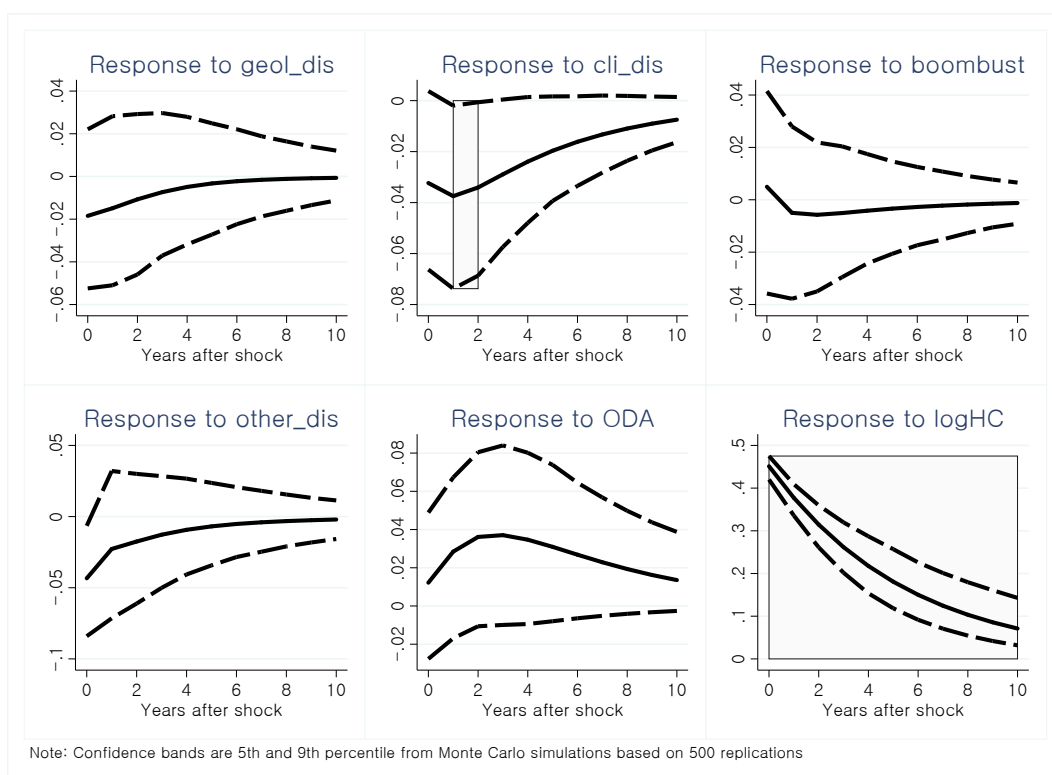


Figure 32: Response of Tropical Country Natural Capital (log)

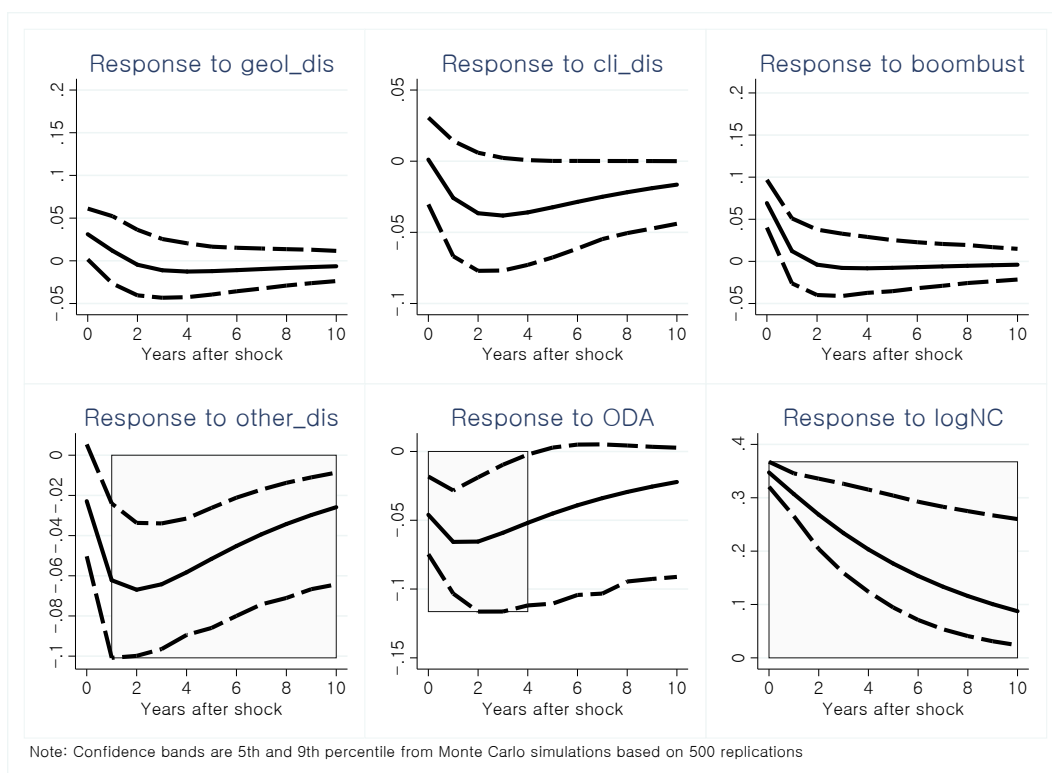


Figure 33: Response of Tropical Country Physical Capital *Ratio* (log)

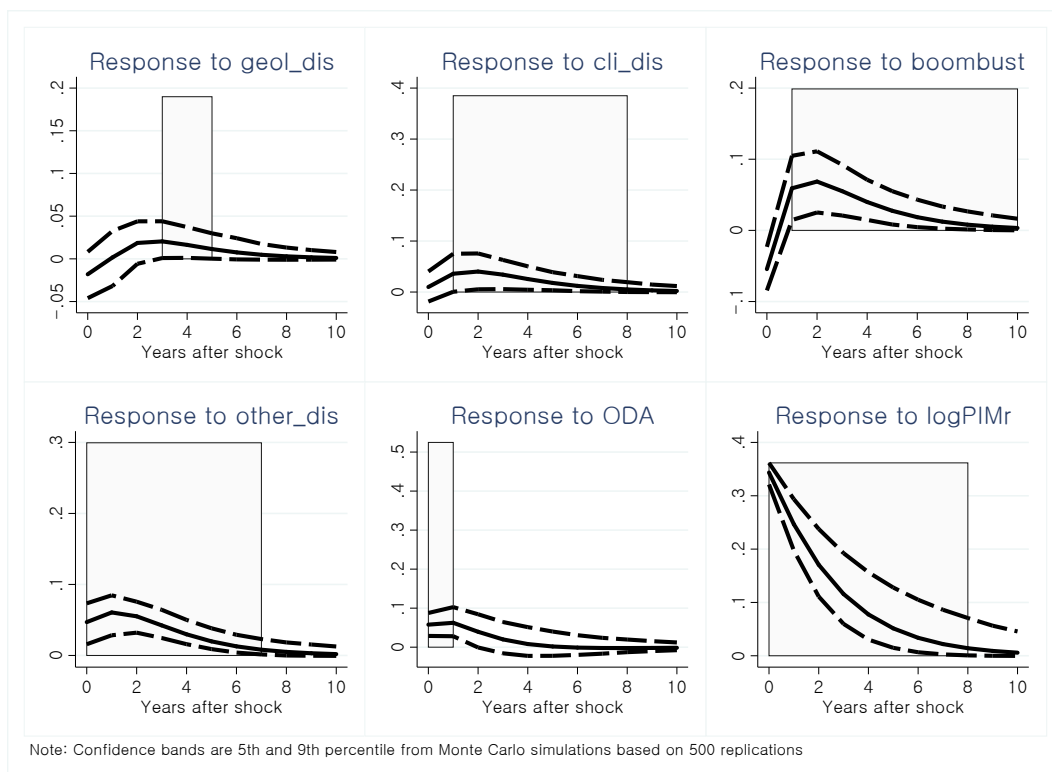


Figure 33: Response of Tropical Country Human Capital Ratio (log)

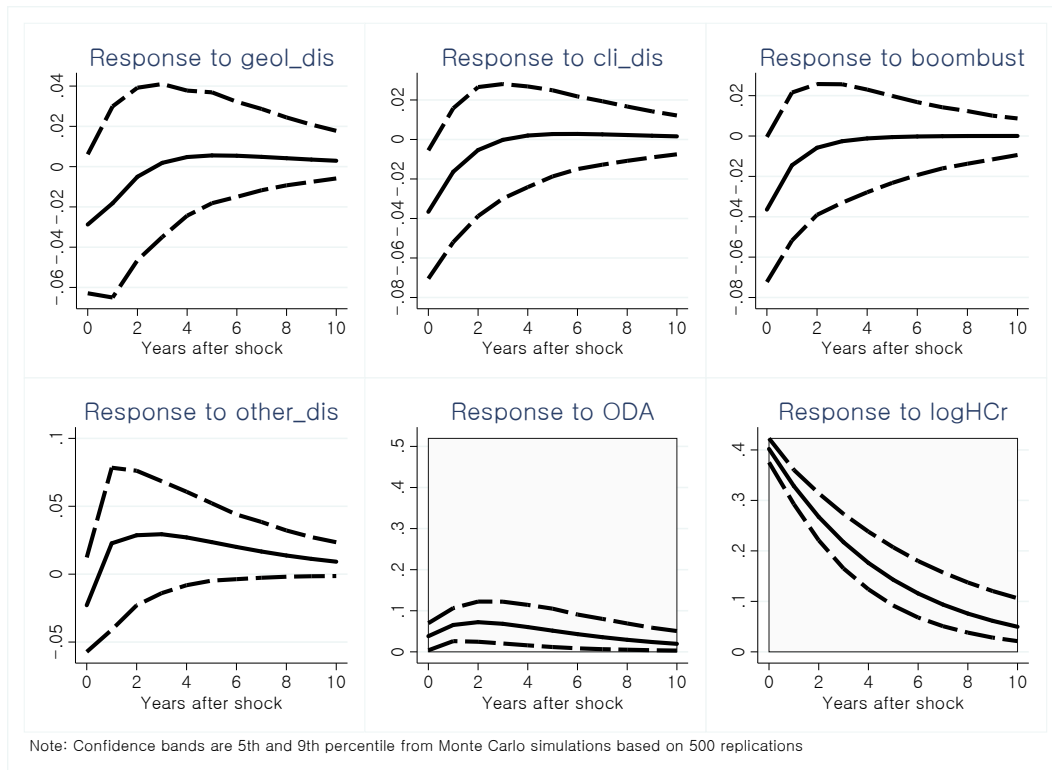
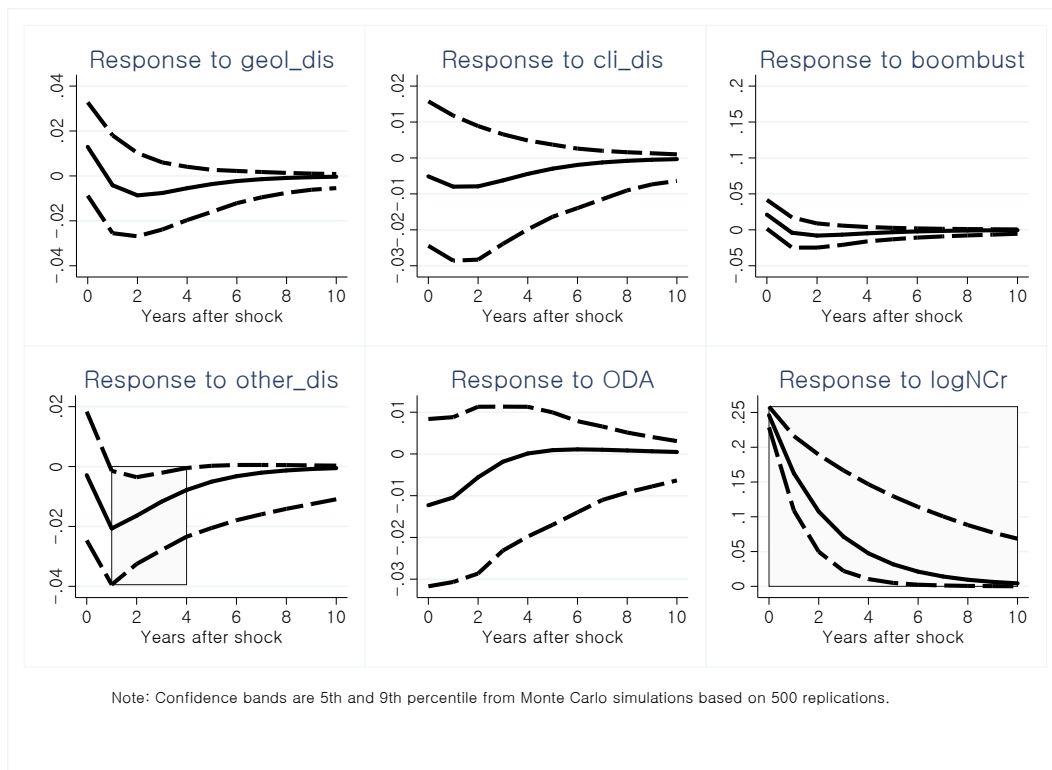


Figure 33: Response of Tropical Country Natural Capital Ratio (log)



D. Tables

Table C

Panel Variables: statistics for Levin-Lin-Chu unit root test

Variable	Unadjusted t	Adjusted t*	P-value	Obs	Lag trunc.
	(1)	(2)	(3)	(4)	(5)
Human Capital (log)	-12.176	-3.352	0.0004	810	9
Physical Capital (log)	-14.745	-5.076	0.0000	810	9
Natural Capital (log)	-14.656	-4.199	0.0000	810	9
Official Development Aid (log)	-9.508	-2.363	0.0091	405	9

Results for the Levin et al. (2002) panel unit root test. Column (1) and (2) report the standard and modified t-values of the orthogonalised residuals. Column (3) reports the p-value for the null hypothesis that the panels contain unit roots. Column (4) reports the number of observations used. Only countries for which strongly balanced series were available could be used for the unit root test. Therefore, the number of observations used here is a bit smaller than the one used in the regressions. Results do not change significantly when regressions are run with this sample. Only countries that receive Official Development Assistance (ODA) are used in ODA's unit root test. Column (5) reports the maximum number of lags used, according to the Bartlett kernel and Newey and West's method. A time trend was included in all tests.

Table D.

Variation in Row Variable Explained by Column Variable

Response Variable	Forecast (years)	Geological Disaster	Climatic Disaster	CTOT Shock	Other Disaster	ODA Shock	Shock by Response Variable
Figure 1							
Wealth	5	0.72%	0.06%	1.06%	0.92%	0.23%	97.00%
Wealth	10	0.65%	0.07%	1.50%	0.89%	0.47%	96.42%
Figure 2-4							
Physical Capital	5	0.17%	0.98%	1.69%	0.64%	2.25%	94.26%
Physical Capital	10	0.19%	1.49%	1.91%	0.68%	2.37%	93.36%
Human Capital	5	0.31%	0.39%	0.20%	0.26%	5.45%	93.38%
Human Capital	10	0.45%	0.39%	0.26%	0.90%	9.84%	88.16%
Natural Capital	5	1.53%	0.07%	0.29%	0.75%	0.11%	97.25%
Natural Capital	10	1.37%	0.10%	0.24%	0.90%	0.13%	97.25%
Figure 5-7							
Physical Capital, ratio	5	0.67%	0.10%	2.38%	1.90%	2.12%	92.83%
Physical Capital, ratio	10	0.70%	0.25%	3.36%	2.33%	2.88%	90.48%
Human Capital, ratio	5	0.9%	0.08%	3.12%	0.22%	1.1%	94.51%
Human Capital, ratio	10	0.99%	0.21%	4.40%	0.53%	1.82%	92.05%
Natural Capital, ratio	5	1.07%	0.06%	3.96%	0.20%	0.43%	94.28%
Natural Capital, ratio	10	1.17%	0.19%	5.34%	0.40%	0.80%	92.10%

Table E.

Variation in Row Variable Explained by Column Variable

Response Variable	Forecast (years)	Geological Disaster	Climatic Disaster	CTOT Shock	Other Disaster	ODA Shock	Shock by Response Variable
First Difference							
Wealth (log)	5	3.19%	0.60%	1.86%	0.34%	0.20%	93.82%
Wealth (log)	10	3.63%	0.76%	1.97%	0.40%	0.21%	93.03%
Cholesky - Other Disasters							
Wealth (log)	5	0.72%	0.06%	0.95%	1.03%	0.23%	97.00%
Wealth (log)	10	0.65%	0.07%	0.92%	1.46%	0.47%	96.42%
Only Tropics							
Wealth (log)	5	0.17%	0.64%	1.07%	2.63%	3.57%	91.92%
Wealth (log)	10	0.13%	0.89%	0.81%	3.20%	4.18%	90.79%
One Lag							
Wealth (log)	5	0.99%	0.55%	0.17%	1.22%	1.21%	95.86%
Wealth (log)	10	1.17%	0.69%	0.16%	1.43%	1.43%	95.12%
Five Lags							
Wealth (log)	5	0.83%	0.06%	0.64%	0.76%	0.22%	97.49%
Wealth (log)	10	0.79%	0.15%	0.57%	1.74%	0.32%	96.43%
1985-2002 sample							
Wealth (log)	5	3.12%	0.08%	0.62%	0.92%	0.68%	94.57%
Wealth (log)	10	3.24%	0.09%	0.62%	0.92%	0.81%	94.33%
Only Developing Countries							
Wealth (log)	5	0.17%	1.17%	0.12%	2.27%	4.67%	91.60%
Wealth (log)	10	0.19%	1.36%	0.14%	2.62%	6.92%	88.76%

Table F.

Occurrence of Natural Disasters and Commodity Price Fluctuations

Geological Disaster

Argentina, China, Greece, Indonesia (3), Iran, Japan (3), Malaysia, Mexico (5), Pakistan

Climatic Disaster

Argentina (3), Australia, Bangladesh (9), Brazil (3), China (7), Denmark, Greece, Indonesia (3), Iran, Malaysia (6), Mexico (5), Pakistan (4)

Other Disaster

Bangladesh (3), Denmark, Greece (4), Indonesia (5), Japan, Malaysia (7), Mexico (3)

Commodity Terms-of-Trade Fluctuations

Algeria, Argentina (2), Australia, Canada, Denmark (2), Egypt (2), Hungary, India (2), Indonesia (3), Kuwait (2), Mexico (2), Norway (2), Pakistan, Saudi Arabia, South Africa (2), South Korea, Spain (2), Syria (2), Thailand (2), Tunisia, Turkey, United Kingdom

Note: the number in hyphens indicates the number of times a shock has occurred in the country (only if more than once).