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Raising the bar: on the type, size and timeline of a “successful” decoupling

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Abstract.

Decoupling environmental “bads” from economic “goods” is a key part of policies, such as green growth and circular economy, that see economic growth as desiderable or necessary, and also see that current use of natural resources and its environmental impacts are unsustainable. We estimate what a “successful decoupling” (2% annual GDP growth and a decline in resource use by 2050 to a level that could be sustainable and compatible with a maximum 2°C global warming) would mean in terms of its type, timeline and size. Compared to 2017, “successful” decoupling has to result in 2.6 times more GDP out of every ton of material use, including in-use material stocks. There are no realistic scenarios for such an increase in resource productivity.

1. Introduction

Decoupling the environmental impact and resource use of an economy from its size and growth has been a watchword for policy paradigms since the 1990s (e.g., Ekins 2000; OECD 2001). The main motivation for the attention is easy to identify. Mainstream economic policies see economic growth a necessity for continued well-being, poverty reduction, upholding public funds and even for environmental improvements (UNEP 2011a, 2014). At the same time, the current environmental impact and resource use of many national economies and their global sum is unsustainable (IRP 2017, IGS 2019). Consequently, if the economy is to grow or even stay at the current level, it has to be decoupled from its environmental impact and fitted inside planetary boundaries of resource use, implying that economic paradigms that are explicitly pro-growth and pro-environment, such as “circular economy” (Murray, Skene & Haynes 2017) and “green growth” (UNEP 2011b), rely on the idea of decoupling.

The literature contains robust evidence for certain types of decoupling, such as decreased CO2 emissions combined with economic growth in certain OECD economies (UNEP 2011a, 2014). However, it is not clear what the relevance of this kinds of evidence is in view of the radical changes needed for human economies to stay within a safe zone of multiple planetary boundaries (Rockström et al. 2009), including rate of biodiversity loss, ocean acidification, global freshwater use, change in land use and resource use (IPBES 2019, IRP 2017), out of which climate change is only one, albeit a pressing one (IPCC 2018). Our aim is to provide clarifying context by estimating what kind of decoupling is needed. First, we discuss different types of decoupling, and on that basis focus on current analyses of resource use. Second, we shortly review empirical evidence on decoupling. The review is not intended as a comprehensive presentation of the rapidly increasing literature; for our purposes it is enough to outline the observation that no evidence for the needed kind of decoupling exists, as of now. Third, based on existing research, we estimate what “successful” decoupling would imply in terms of size and timescale. The estimation is intended as a tool for assessing empirically motivated claims for or against decoupling in policy contexts.

2. The Need for Decoupling

2.1 Definitions

“Decoupling” is used here to refer to the end of the connection between increased economic production and decreased environmental quality. Two forms of decoupling, relative (weak) and absolute (strong) are distinguished in the literature. *Relative decoupling* refers to a decline in ecological/resource intensity per unit of economic output. In relative decoupling, environmental impacts and/or resource use decline relative to the economic output, while both could still be rising. *Absolute decoupling* refers to a decline in impacts and/or resource use in absolute terms, while the economy grows (or stays stable).

When the concept is operationalised, different metrics are used to quantify both the economy and its environmental impact and/or resource use. On the side of socio-ecological measurements the metrics include, e.g., population growth, water use, energy use, resource use, and biodiversity, while economic output is more uniformly defined in terms of gross domestic production (GDP). Decoupling with regard to the environmental “bads”, such as emissions and pollution, resulting from economic activity, is called *impact* decoupling, while decoupling economic activity from resource use is called *resource* decoupling.

2.2 Types of Decoupling

It is important to notice that the real world phenomena discussed in the literature under the abstract concept of decoupling are quite different. Decoupling can be discussed or observed with regard to a more or less bounded geographical or administrative area (city, municipality, region, nation, the globe, etc.), a specific economic sector (agriculture, construction, etc.), across several sectors or the whole economy, and during a shorter or longer time interval (see also Parrique et al 2019). There is a clear difference in how easy or how hard it is to achieve decoupling along these three axes. The bigger the economic area and the more comprehensive the view over the economy, the harder the task of decoupling becomes. Likewise, decoupling is easier to achieve over a limited time period than as a sustained and ongoing phenomenon.

Along these axes, one type of decoupling is not necessarily (logically) connected to other types of decoupling at all – meaning also that empirical evidence of one type of decoupling is not, without further qualification, relevant for other types of decoupling. For instance, impact decoupling, in general, is not logically connected to resource decoupling: impact decoupling can co-exist with resource decoupling (e.g., when a harmful substance is eliminated from production completely) as well as increased resource use (e.g., when a harmful substance is replaced by another substance the production of which requires more material resources and/

or energy). As an aggregate, resource use correlates with many environmental impacts, but different resource use indicators on, e.g., direct domestic use of material, embodied material use in supply chains and in-use stock of materials may give different answers to the question if decoupling is happening or not (Zhang et al 2018). Moreover, within the aggregate individual resource categories (such as sand, ocean fish, potable water, oil, etc.) have very different impact dynamics. Consequently, it is important to note that when resource use is expressed in quantitative terms such as domestic material consumption (DMC) or material footprint (MF), the numbers gloss over crucial qualitative aspects. In order to be ecologically sustainable, the total sum of resource use, whatever the exact number in tons, can not contain the unsustainable use of any subcomponent, i.e., any specific natural resource. In the following we are assuming, for the sake of the argument, that a quantitatively sustainable resource use is also qualitatively sustainable.

Likewise, the existence of decoupling in a bounded geographical area or economic sector does not, as such, mean that decoupling is happening in a wider context. Well-known and widely studied phenomena such as Jevons' paradox (Alcott 2005), rebound, and outsourcing show that sectoral and local decoupling can co-exist with and even depend on increased environmental impact and increased resource use outside the analysed geographical or sectoral unit.

The phenomenon where increased technological efficiency results in increased overall consumption is known as Jevons' paradox. The rebound in consumption is seen to be caused by the reduced cost of the resource; a phenomenon often noticed with regard to energy (UKERC 2007, Sorrell 2009; Magee & Devezas 2017). Magee and Devezas (2017) go through 57 cases of key materials or technological artefacts on a global level and show that, because of rebound, consistent dematerialization has not taken place despite high level of technological progress in some fields (e.g., a hard disk drive). However, “[a]n optimistic possibility yet remains: drastic substitution (on a functional and system basis) of more benign technologies where such technologies result from continuing technological change.” (Magee & Devezas 2017) This means that functions such as travel or housing would be realized in radically different ways by changing the technological pathway – making rebound also an issue of policy (see also O’Neill et al. 2018). Also measures addressing consumption, such as taxation (Freire-Gonzales & Puig-Ventosa 2015), can counteract the tendency to rebound.

Similarly, local impacts of resource extraction are avoided by outsourcing, with low- and mid-income regions producing primary exports to high-income countries (IRP 2017). When the indirect material flows that high-income countries receive in the products that they import are taken into account, high-income countries such as the USA, UK, Japan, the OECD and EU-27 have not achieved decoupling (Wiedmann et al. 2015); on the contrary, in many cases re-coupling has occurred.

Rebound and outsourcing show that in interpreting the global relevance of findings of geographically limited and sector-specific decoupling, one has to look beyond the specific sector or locality being studied. There are also other phenomena studied in the literature, such as financialisation (Kovacic et al 2017), that indicate the need for a wider lense in the interpretation of empirical evidence. The crucial point is that sectorally and geographically limited decoupling is logically independent from larger scale decoupling, and can co-exist with (and even depend on) increased negative impacts or resource use outside the analysed sector or area. This logical disconnect means that optimism about decoupling should not, without further argument, be carried over from the cases of sectoral and geographically limited impact decoupling to global absolute resource decoupling.

Sectorally and geographically specific and temporally limited impact decoupling is an easier target than economy-wide, global and ongoing resource decoupling, simply because the former types imply fewer changes in the overall metabolism of the economy. However, since the global level of resource use is unsustainable, the hardest kind of decoupling, absolute ongoing global resource decoupling is needed in addition to the easier types of geographically, sectorally and temporally limited decouplings. Moreover, in view of the fact that overstepping tipping points in planetary ecological boundaries may be irreversible (Lenton 2011, Lenton et al 2019), the absolute global resource decoupling has to be sufficiently fast. In sum, when evaluating decoupling as an overarching societal goal, it is important to keep track of the most ambitious goal, because it, too, along the other easier forms of decoupling, has to be achieved, and because it provides the best proxy for staying within planetary boundaries.

2.3 Global Material Trends

Global use of material resources has increased tenfold from 1900 to present, from less than 10 Gt/year to roughly 88.6 Gt in 2017 (Krausmann et al. 2009; Krausmann et al. 2017; IRP 2017) as the physical economy grew faster than population (Krausmann et al 2009; Schaffartzik et al 2014). Importantly, the rate of growth has accelerated, as consumption more than tripled in the decades since 1970. The present consumption pattern is wasteful:

only 9-12 percent of materials are recycled (Krausmann *et al.* 2017; The Circularity Gap Report 2018).

Of all resource use, about half is used to provide energy in a broad sense. The other half of is used to build up or renew in-use stocks, for example, buildings, transport infrastructure, machines, and consumer goods (Krausmann *et al.* 2017, Krausmann et al. 2020). From 1900 to 2010, while global material extraction grew 10-fold, the share of extraction for stock-building materials rose from 18 to 55 percent, so that global material stocks grew 23-fold. (Krausmann *et al.* 2017). Krausmann et al (2017, 5) emphasise that the "convergence of material stocks at the high level of industrial countries is not compatible with the global climate change mitigation target agreed in Paris in 2015."

Both population growth and increased affluence are driving higher material use, but in somewhat different ways around the globe, as observed by the International Resource Panel (2017, 40): "Population growth was the strongest driver in Africa and West Asia. In North America and Asia and the Pacific, growing affluence and consumption had a larger influence on expanding material footprints than population growth." The difference is connected to the observed rise in inequality in consumption (IGS 2019).

As one possible solution, Krausmann *et al.* (2017) and Kraussman et al. (2020) suggest that by 2050 the per capita stock level in industrial countries would be returned to what it was at around 1970, e.g., through diminishing the amount of infrastructure and buildings in need of upkeep and making the remaining stock much more efficient, while allowing the developing countries to enlarge their stocks to a moderate level (that would need to be extremely efficient, too).

As a summary of the present global resource extraction rates and growth, the 2017 International Resource Panel report (IRP 2017, 47) provides two insights:

> 1) Environmental impacts – including pollution and climate pressure – cannot be mitigated effectively without reducing raw material inputs into production and consumption, because their throughput determines the magnitude of final waste and emissions released to the environment. 2) Decoupling economic activity and human well-being from resource use – in the form of enhanced resource efficiency – is necessary to achieve the Sustainable Development Goals for all.

While relative decoupling may be regionally or sectorally desirable (and increased material use can be encouraged in developing economies and specific sectors), only absolute decoupling on the global scale, i.e., decreasing material use, is consistent with ecological sustainability and realising the SDGs without transgressing planetary boundaries.

3. Decoupling: the Evidence

There is evidence for both relative impact and relative resource decoupling (e.g., UNEP 2011a, 2014; Kovacic et al 2017; Kraussmann et al 2009). In general, relative decoupling of energy and material use and CO2 emissions from GDP has been observed as a trend for decades, due to improved efficiency. However, periods of absolute decoupling have been short and geographically and/or sectorally limited. Absolute decoupling has been observed only in some industrialized countries (such as the UK, Germany, Japan, etc., see Steinberger et al. 2013, Giljum et al. 2014, Hickel & Kallis 2019), especially connected to periods of recession or low growth (Shao et al. 2017).

In the following we present results from a bibliometric review and more general observations on the empirical evidence. A bibliometric survey of the terms “decoupling”, “economic” and “environment” using Thomson Reuters’ Web of Science database was conducted (October 4., 2018) for years 1990-2018. The survey returned 178 articles, where all of these terms appear in the title, abstract or keywords. Using search words “decoupling” and “economic” returned 1244 articles, and using words “decoupling” and “environment” returned 1731 articles. This suggests that although decoupling as a term has been fairly thoroughly investigated, most of the research during the last 30 years has concentrated on a single subject field, from an environmental or an economic perspective. For all 178 articles the total citation count is 1864. More than half of these citations are from the last three years (2016 = 215, 2017 = 398, 2018 = 441). The numbers indicate that although the term has a long history, and is used frequently in policy discussions, the available published research is just emerging. In the set of 178 articles, 124 discuss the phenomenon of decoupling, but do not present new empirical data, and are therefore left out of the analysis. Out of the 54 papers with empirical data, 10 studies present evidence of absolute decoupling. All but one of those 10 studies present results on a limited geographical area, and none of those 9 regionally limited studies takes into account the role of outsourcing and trade.

The only exception is Wood *et al.* (2018), who use EXIOBASE3, a global multiregional input-output (MRIO) model compiled explicitly to investigate the role of international trade in relation to resource efficiency. They calculate both production and consumption based indices for green house gas (GHG) emissions, energy use, material use, water consumption, and land use for the period of 1995-2011. To quote from their conclusion:

> On a global scale, achievements in resource efficiency, which are characterized by either absolute or strong relative decoupling from GDP, have been limited. [...] Material use has shown the strongest increase, from 8.3 to 11.3 tonnes/capita (+36%), outstripping growth in GDP. We also see an equal growth of GHG emissions to emissions-relevant energy use, [...]. Land and water re-sources, which are more directly subject to natural constraints, have increased the least, with blue water consumption rising from 190 to 200 cubic meters/capita, and the total surface area of land used for productive purposes showing a reduction of 0.3 hectares/capita [...] It is the only indicator that presented (small) absolute decoupling from GDP.

Combined with the discussion on types of decoupling, above, the review of empirical evidence can be summarised as follows. There is no evidence of ongoing, global absolute resource decoupling. On the contrary, global resource use is growing (IRP 2017, Wood et al 2018). Cases where resource use diminishes while GDP grows can be found in a specific economic sector (such as agriculture) and a bounded geographical area. The review is supported by studies that explore the potential of aggressive policy measures and gains in technological efficiency, and find no evidence that absolute decoupling will result in the decades up to 2050 (Dittrich *et al.* 2012, Schadl *et al.* 2016). Likewise, the most optimistic Climate Plus-scenario by the International Resource Panel (2017, 44) which includes aggressive climate mitigation plus maximal increase in efficiency of material use, projects that global material extraction would expand by around 75 per cent by 2050 – demonstrating the inertia of current systems of production, consumption and lock-ins from existing stocks that result in long-lasting legacies for material requirements.

The discrepancy between the optimism created by observations of relative decoupling and the lack of evidence of absolute decoupling is largely explained by the role of trade and ourtsourcing in global economy. A large shift has occurred in material extraction from Europe and North America to Asia, the Pacific and West Asian regions (IRP 2017). Bithas & Kalimeris (2017) observe two trends: a consistent dematerialisation in Europe, a less robust dematerialisation in North America and Oceania, and an increased materialisation in Africa, Asia, Middle-East and Latin America. They (2017, 343-344) sum up: “Global materialization is largely the result of the performance of the developing continents which must be seen in the light of the dematerialization of the developed continents.”

Another possible source of misleading results is financialisation, i.e., the growth of the financial sector relative to other economic sectors. The onset of financialisation in high-income countries is traced back to 1980s, and the time after the financial crisis of 2008 is noteworthy as several economic actors, including the US, EU, Japan and China, have established extraordinary financial policies such as quantitative easing and near-zero central bank interest rates (van der Zwan 2014; van Treeck 2009). Financialisation can indirectly lead to increased GDP, and consequently to relative decoupling. In this kind of “financialised decoupling” the material footprint stays the same (or grows), but carries “on top” an (even faster) enlarged financial sector (Fletcher & Rammelt 2016; Kovacic *et al.* 2017).

In a recent study Kovacic *et al.* (2017) look at EU14 countries between the years 1995-2013. During that time, the energy intensity of the economies fell ca. 20 percent, thus clearly indicating decoupling. However, at the same time, the financial intensity (defined as the sum of financial assets divided by GDP) grew even faster, ca. 60 percent. The authors further analytically divide the economy into three parts, FINance, GOVernment and DE* (DE* including all the rest: agriculture, manufacturing, transport, building and so on, i.e., the majority of all physical activity of moving and transforming materials). During the period analysed, the energy intensity of DE* (defined as energy used divided by worked hours) has remained constant. The authors conclude that because the energy use of FIN and GOV is in any case relatively small (compared to DE*), the observed decrease of energy intensity is due to the growth of financial assets which has ballooned the GDP. As the energy intensity of DE* has not declined, Kovacic et al (2017) deduce that "the decoupling between energy throughput and economic growth in the EU14 reflects a process of financialization, rather than a change in metabolic patterns or production processes."

4. Successful Decoupling – Timeline and Size

In order to concretize the discussion, we choose a rough quantitative timeline and size of needed absolute global resource decoupling, based on international agreements and recent research (Paris Agreement 2016; IPR 2017; Krausmann *et al.* 2009; Krausmann *et al.* 2017; Krausmann *et al.* 2020). As is well known, due to uncertainties in climate sensitivity and modeling, and the possibility of irreversible tipping-points, it is impossible to give a definite date before which specific climate mitigation efforts have to be implemented, and the effects of aggregated greenhouse gases (GHG) will continue after emission mitigation deadlines. Analogously, it is impossible to determine a definite date when current unsustainable resource use has to be made sustainable. However, on the basis of wide and detailed synthetic summaries (e.g., IPCC 2018), climate research and policy have identified rough deadlines for the most important mitigation targets. These targets, as embedded in international agreements, give also a minimum goal for resource use: resource use should be at a level that, at the very least, makes achievement of the climate mitigation targets possible.

An added complication is that a given quantitative aggregate level of resource use is not directly identical with a given level of GHG emissions: the emission level is crucially dependent on the qualities of resources within the aggregate. Consequently, in the following, we choose a level of resource use that, according to estimates in the literature, *could* be compatible with the climate targets. However, there is no guarantee that it will be. The time window for meaningful mitigation of the worst effects of climate change is from the present until 2050 (IPCC 2018; Rockström *et al.* 2017). We choose this timeline also for a successful decoupling.

For the sake of the argument, we define a "successful decoupling" conservatively as one that *could* be sustainable in material terms and *could* be compatible with stopping temperature rise to 2°C. We will take the data of IPR (2017) as a starting point for global resource use and use 9.7 billion as the global population by 2050 (in the median range of UN World Population Prospects 2017, https://esa.un.org/unpd/wpp/). A level of sustainable use conceivably compatible (Krausmann et al 2017) with Paris Agreement goals would be around 68 billion tonnes (roughly the level of resource use in year 2000), entailing a per capita use of ca. 7 tonnes in 2050 (compare Bringezu 2015; Tukker *et al.* 2016). Correspondingly, taking a modest yearly growth rate of 2 %, the size of the economy in 2050 would be ca. 150 000 billion USD (starting from the global GDP of 80 000 billion in 2017 reported by the IMF, http://www.imf.org/external/pubs/ft/weo/2017/02/weodata/index.aspx).

[Figure 1 near here]

Figure 1. GDP (USD) per tonnes of material. The figure shows GDP per tonnes of material use, i.e., it represents how much GDP the economy is able to generate from the materials used. The projection of global population is based on UN World Population Prospects, the projection of material use on IRP (2017) and the projection of GDP on IMF reports (see main text for references). The black line depicts the observed rate 1980-2017. Although it shows periods of decoupling, the observed decoupling is not "successful" in our definition, as it is not quantitatively sufficient and not fast enough. After 2017, the projections presuppose 2% growth in GDP. The grey line corresponds to material use staying at the level of 2015 and the red line corresponds to Business-as-Usual scenario (from IRP 2017). The green line depicts the scenario of material use of 7 tons per capita in 2050. The dotted green line presents a scenario where action is postponed until 2030 after which the reduction of material use is fast-tracked to reach 7 tons per capita in 2050. The (dotted) green line, then, in our estimation depicts a "successful decoupling", implying a modest GDP growth of 2% from 2017 to 2050, and a per capita use of materials of 7 tonnes in 2050 (for the sake of the argument, we neglect the fact that in the meantime, before 2050, material use is higher, possibly entailing ecological unsustainability and serious tipping points even if the 2050 target is reached).

In the "successful decoupling" (Figure 1), world total GDP doubles compared to 2017 while global resource use per capita decreases by ca. 42%. More specifically, this means a halving of per capita resource use in Europe and a cut of ⅔ in per capita use in North America. Globally, the amount of GDP created by every billion tons of resource extraction in 2050 would be ca. 2.4 billion USD compared to ca. 0.9 billion USD in 2017; a formidable task given that half of all resource use goes towards the upkeep of existing stock and that the current trend is a decrease in the GDP productivity of material extraction (IPR 2017) and stock use (Krausmann et al 2017), resulting in declining global material efficiency (Schandl et al 2017).

On the impact side, a similar argument is presented by Antal & van den Bergh (2014; see also Anderson & Bows 2011) who analyse the needed decoupling in terms of GHG emissions to stay under the limit of 2°C global warming. They find that given a moderate 1.5 percent annual per capita GDP growth, the needed annual reduction in GHG emissions per unit of GDP (emission intensity) is 4.4 percent, and 2.9 percent for 0 percent annual GDP growth. Even a 2.9 percent reduction is considerably larger than the historical average reduction of intensity at less than 1.5 percent over the period 1970 – 2013 (2014, 3). Antal & van den Bergh (2014, 7) conclude that “decoupling as a main or single strategy to combine economic and environmental aims should be judged as taking a very large risk with our common future.” Likewise, in their review of climate change mitigation scenarios (including the scnearios of the IPCC’s Fifth Assessment Report (AR5) consistent with Representative Concentration Pathway 2.6 (RCP2.6), Schandl *et al.* (2016), IRENA (2018) and Grubler *et al.* (2018)), Hickel and Kallis (2019) find that “The empirical data demonstrate that while absolute decoupling of GDP from emissions is possible and is already happening in some regions, it is unlikely to happen fast enough to respect the carbon budgets for 1.5°C and 2°C against a background of continued economic growth.”

For absolute resource decoupling to make sense as a global goal, we would need a scenario where, in ca. 30 years, the economy produces 2.6. times more GDP out of every ton of material used, under conditions where material use diminishes ca. 40 % globally. Currently no trends corresponding to this scenario are observable and, to our knowledge, no concrete proposals with such a level of decoupling have been presented.

5. Conclusion

While the perceived need for economic growth together with observations of increased economic productivity with respect to resource units and environmental impacts prompt a vision of decoupling, evidence of absolute decoupling is missing. The existing research contains evidence of impact decoupling, and sectoral and geographically limited resource decoupling. However, these types of decoupling are also logically compatible with increased global resource use, as phenomena such as rebound and outsourcing show. Therefore, the evidence, as it exists, does not without further detailed analysis point towards the ecologically sufficient and necessary goal of absolute global resource decoupling.

The lack of evidence demonstrates the inertia of current systems of production and consumption and lock-in with regard to important infrastructure with long-lasting legacies for material requirements. A global GDP growth of 2 % until 2050 would necessitate a “successful absolute resource decoupling” with 2.6 more GDP produced by every ton of material use, for which no realistic scenario exists. Existing evidence does not support the conclusion that the right type of decoupling would be happening fast enough, and even a crude estimate of the needed timescale suggests that expectation of success is unrealistic.

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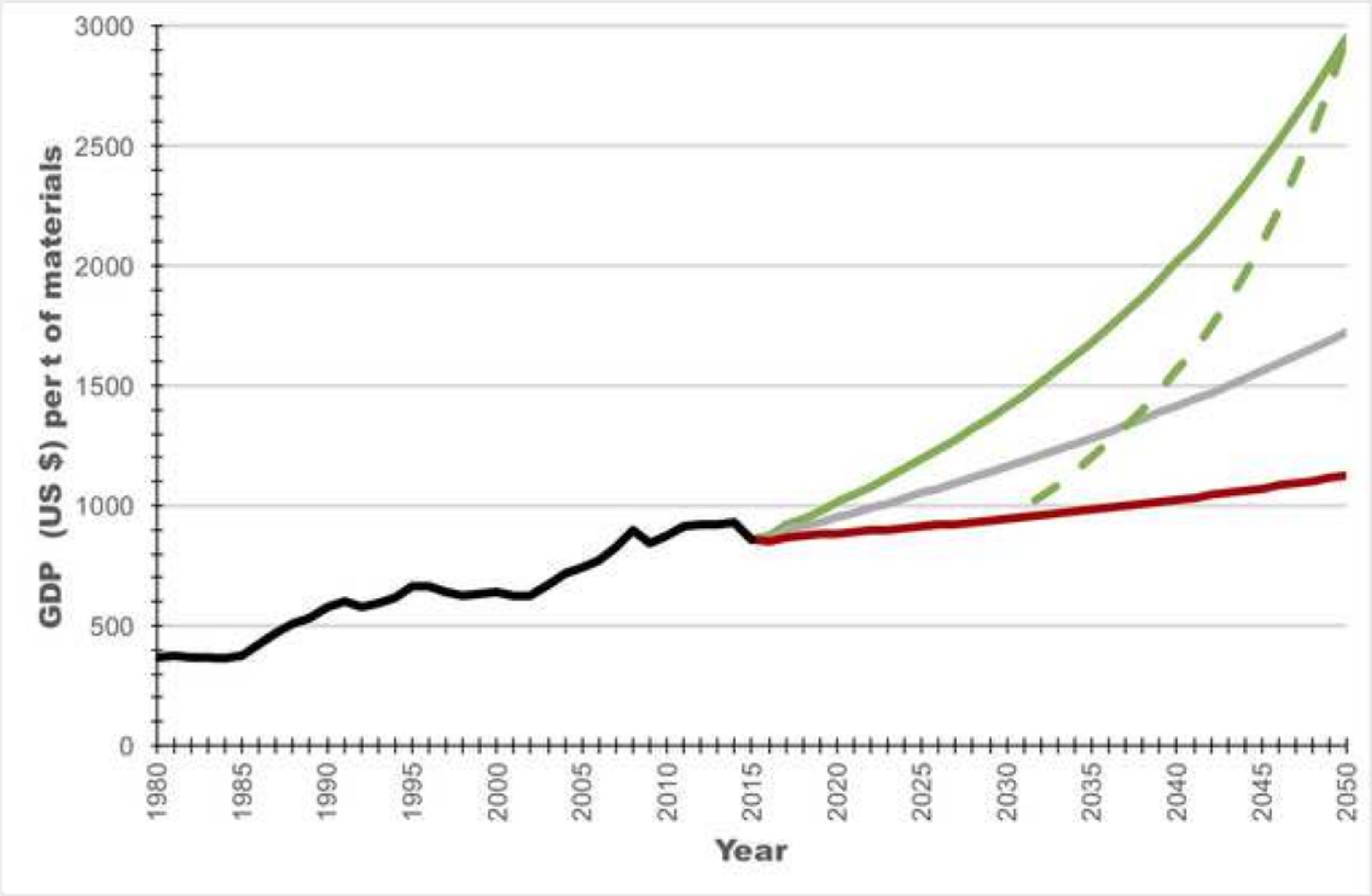
Figure


GDP (US $) per t of materials
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year