Rankings for Carbon Emissions and Economic Growth Decoupling

Mariana Conte Grand

Abstract The main purpose of this chapter is to analyze decoupling between carbon emissions and economic activity for the different countries in the world within the 1990–2012 period. We qualify decoupling cases. Countries are ranked from those that decrease emissions while expanding activity (strong decoupling) to those that augment their greenhouse gases and are in recession (strong negative decoupling). For the cases in which there exists a conflict between growth and emissions (there is improvement in one indicator and worse conditions for the other), the orderings are two, depending if priority is given to the economy or to nature. The findings are that 30% of countries follow green growth paths, 50% weakly decouple their emissions from activity (emissions increase less than GDP), and 20% decouple expansively (their emissions increase more than GDP). There is almost difference between ranking countries giving priority to growth and prioritizing nature. Argentina ranks approximately in the 60th place among around 150 countries in the database and is one of the developing countries that weakly decoupled carbon emissions from economic activity in the period under study.

Keywords Carbon emissions · Decoupling indicators · Degrowth · Green growth · A-growth · Sustainable development

Introduction

As it is well known, the Paris Agreement (PA) main objective is to keep the average increase of global temperature at least below 2 °C with respect to pre-industrial levels by the end of the century in order to avoid massive damages due to climate change. Several research groups analyze the gap between the emissions levels needed to honor that goal and the Parties' climate policies. They conclude that the attainment

M. Conte Grand (✉)
Department of Economics, Universidad del CEMA, Av. Córdoba 374, C1054AAP Ciudad Autónoma de Buenos Aires, Argentina
e-mail: mcg@ucema.edu.ar

M. E. Belfiori and M. J. Rabassa, (eds.) *The Economics of Climate Change in Argentina*, The Latin American Studies Book Series,
https://doi.org/10.1007/978-3-030-62252-7_4

of the 2° goal requires greenhouse gases (GHG) reductions of 40–70% by 2050, with respect to 2010 (IPCC 2014).

There is a gap between mitigation policies and what is needed to attenuate the consequences of climate change. The gap occurs because that even if the current national commitments under the PA were fully implemented, the target is still far from being reached. In fact, as shown by UNEP (2017), the carbon budget (i.e., carbon allowed emissions by 2100) would be 80% depleted by 2030 (the date of the PA promises). By 2030, there would be a gap to get the world to the 2° trajectory. This happens because greenhouse gases need to be 42 gigatonnes of CO_2 equivalent ($GtCO_2$-e) per year by 2030, and with the PA Nationally Determined Contributions (NDCs), they would be 11–13 $GtCO_2$-e higher.

The only way to grow and fulfill the goal of the Paris agreement is by decoupling economic activities from carbon emissions. According to the Merriam-Webster dictionary, to decouple is "to eliminate the interrelationship of" or "separate." More specifically, OECD (2002) defines decoupling as "breaking the link between environmental bads and economic goods."

The relationship between emissions and GDP evolves differently for each country. This link depends on what and how each of them produces (and consumes). A priori, those economies with a high share of services in value added relative to that of industry or agriculture would be more able to decrease their greenhouse gases to a greater extent, and the opposite would occur for those countries that are major oil producers. However, the profile of each economy is determined by factors that include own initial endowments, technology innovation and changes in consumers' attitude toward the environment. And public policies influence all of them. Decoupling is not automatically attained; it has to be driven by both market and government policy forces (Stavins 2016). And, what is most important in terms of this chapter is that not all types of decoupling are equally desirable.

Different Views About the Relationship Between Economic Growth and the Environment

There are all kinds of difficulties in agreeing on stricter emissions' reduction goals. One of them is that developing countries argue that they are not historically responsible for carbon emissions (i.e., their argument is that concentration of GHG increased substantially since the Industrial Revolution, which began in the developed—and not in developing—nations). Another is that there is no single indicator on which countries can agree on. Per capita emissions and emissions intensity—Emissions/GDP—would be simple metrics to agree on reductions, but that is not possible since they differ substantially between countries: nations with low emissions per capita tend to have high emissions' intensity, but the indicators go the other way around for advanced less populated nations. For example, in 2012 (last data available for total GHG emissions per country at the moment this chapter was written), Paraguay and

Uruguay emitted approximately 8 and 10.1 GHG per capita (tCO_2e/population) while their emissions' intensity was 1089 and 545 tCO_2e/million of GDP measured as PPP (constant 2011 international $), respectively.[1] Hence, in that scenario, Paraguay would support an agreement based on its emissions per capita while Uruguay would prefer commitments based on emissions per unit of GDP. In addition, there are also conflicts of incentives. Specifically, since GHG mitigation poses local costs but generates global benefits, individual countries have incentives to pursue low levels of effort, expecting that others will take action (this is the well-known "free-riding" problem).

Moreover, there is agreement that higher levels of economic activity favor reductions in extreme poverty, and there is evidence in that respect in the recent world history (Dollar et al. 2013). However, there is no agreement that a higher world GDP is compatible with lower levels of emissions. There are in fact three distinct views referred to the link between growth and nature (Jakob and Edenhofer 2014). One supports "degrowth" as a way to solve environmental pressure on the planet. A second one states that green growth is possible: It is feasible to reduce "environmental bads" and increase "economic goods." A third one favors a-growth. The latter is represented by "growth agnostics": what is valuable is not economic growth, but rather social progress.

The first view is lead by the followers of the Club of Rome that in the 70s recruited scientists from MIT to study the relationship between growth and the environment. They published the result of their research in The Limits to Growth (Meadows et al. 1972). In that work they concluded that if the increase in the world population, the industrialization, pollution, food production and the natural resources exploitation were maintained without any change, the limits to the planet would be attained in the lapse of one hundred years.

Almost simultaneously with Meadows et al (1972), Georgescu-Roegen (1971) used physics to determine that the earth's resources will eventually be exhausted at some point. Georgescu-Roegen argued that all natural resources are irreversibly degraded when put to use in economic activity; consequently, the carrying capacity of earth to sustain human populations is bound to decrease. He based his ideas on the physical concept of entropy. The second law of thermodynamics (or law of entropy) asserts that a natural process runs only in one sense and is not reversible. For example, heat always flows spontaneously from hotter to colder bodies, and never the reverse. Georgescu-Roegen argued not for a second but fourth law by extending the same

[1]Total greenhouse gas emissions in kt of CO_2 equivalent are composed of CO_2 totals excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N_2O sources and F-gases (HFCs, PFCs and SF6). The data is based on estimated emissions, the countries that are Parties to the United Nations Framework Convention on Climate Change (UNFCCC) use to report to the Convention and follow standardized methodologies recommended by the Intergovernmental Panel on Climate Change (IPCC). Note that from the time this chapter was written, only one year (2013) was added for this variable in the World Bank Development Indicators Database. For years from 2014 to 2019 no data for GHG estimators are reported.

idea of energy to resources: when resources are used for human activities, part of them are lost and are impossible to recover. The ideas of that Romanian scientist were closely followed by one of his students (Daly 1973) and were the base of what is nowadays the brand of economics called "ecological economics".

The followers of that rather pessimistic point of view believe that the limits of the planet are getting closer and the solution is to "degrowth" Weiss and Cattaneo (2017) and Cosme et al. (2017) review all publications in this line of literature and affirm that it has been increasing in the last years. According to the latter authors, from the first academic paper that used the term "degrowth" (in 2006) to date, the number of web pages using that word has multiplied by 20. Strictly speaking, the "degrowth" strategy implies not a continuous decrease of economic activities, but rather a transition to a new steady state that considers the limits of the planet. According to ecological economists, the environmental problems can be attributed to an excessively large economy that goes beyond the capacity of nature. They consider there is a problem of scale (Daly 1973). They do not see economic growth as a solution, but rather as a problem. "Degrowth" is a mean to solve the crisis of the planet. As pointed out by Kallis (2011, p. 874), "sustainable degrowth is not equivalent to negative GDP growth in a growth economy. This has its own name: recession, or if prolonged, depression." The "degrowth" solution consists of reaching a new equilibrium, to then allow a growing economy that uses less resources.

The main criticism to the literature of "degrowth" is that the arguments are well described but its feasibility analysis is poor (see in that respect Martínez-Alier et al. 2010; Cosme et al. 2017; Weiss and Cattaneo 2017). Kallis (2011, p. 874) justify this arguing that "degrowth" is an "umbrella keyword.. It has to do with understanding the limits of nature, not to expect technological miracles. Moreover, Jakob y Edenhofer (2014) point out, based on the IPAT identity (I = P·A·T with "I" denoting **I**mpact–emissions—, "P" = **P**opulation, "A" = **A**ffluence-per capita GDP—and "T" = **T**echnology -emissions per unit of GDP), reducing emissions 5% annually with a 0.7% increase in population, even if GDP does not change, would require a 5.7%, decrease in emissions intensity, which is not low. They state that it makes little sense to attempt to decrease emissions (I) focusing on decreasing growth (A) when in fact it can be made in a more effective way focusing on other type of policies that emphasize changes in population trends and technology (P and T). Finally, even if it may seem attractive to "degrowth" and live a simpler life, working less hours, it can have negative implications for developing economies, where a minimum material quality of life has not been yet attained (see Martínez-Alier et al. 2010, p. 1743 in that respect).

The second point of view, "green growth", is more optimistic. The term has its origin in 2009, when after the financial crisis the Organization for Economic Co-operation and Development (OECD) published the *Declaration on Green Growth.* In its considerations, it states: "Green growth will be relevant going beyond the current crisis, addressing urgent challenges including the fight against climate change and environmental degradation, enhancement of energy security, and the creation of new engines for economic growth." (OECD 2009, p. 1). Green growth followers believe that it is possible to increase economic activities taking into account the environment.

More precisely, they argue that increases in GDP can have low or even negative costs for nature. With "negative costs" they mean that environmental protection can induce the development of green technologies and businesses that can foster the economy even further. Jacobs (2013) differentiates between "strong" and "standard" green growth. The former is the one for which growth considering nature can encourage the development of growth itself. Hence, followers of green growth are optimistic regarding the feasibility of decoupling between carbon emissions and GDP.

The empirical base for "green growth" is the environmental Kuznets curve, according to which more growth sooner or later implies pollution decreases (Grossman and Krueger 1995). The cause of that inverted U shape between economic activity and emissions is that as countries grow, higher income implies technological development and changes in consumers' tastes, and further both go in the direction of a greener economy. Several articles provide a theoretical framework for the environmental Kuznets curve. For example, Stokey (1998), using a representative consumer model, show that "if increased productive capacity allows both consumption growth and improved environmental quality, then growth may continue without bound." However, there are doubts in the literature on the feasibility of occurrence of a classical Kuznets shape for carbon emissions (Dasgupta et al. 2002).

Finally, other economists support a third way, based on the traditional concept of sustainable development. The idea is that economic growth and environmental sustainability are not goals in themselves, but rather social progress is the ultimate target. Under this line, the economy can grow and do so decreasing emissions, but it can also be that social satisfaction is not increasing. That perspective has been named by the term "a-growth", referring to "agnostic growth." Van den Bergh (2011) introduces that word in the Ecological Economics journal (i.e., one of the most important in the field). "A-growth" does not mean to be against growth, but rather against economic growth that does not consider social and environmental sustainability. An example that is often used to illustrate the point is the case of India that has been able to increase GDP but has maintained a low standard of human development, measured by life expectation, health and education levels (Drèze and Sen 2013).

There are several ways to measure social progress. One alternative is to use social welfare functions (Adler 2012), but it is not easy to operationalize this type of functions since they require comparability among individuals. Another option is to use the index of Genuine Savings (GS), which introduces corrections to take into account environmental resources depletion and environmental damages, as well as the investment in human capital (Hamilton 2000). A criticism for the GS indicator is that losses of natural capital are considered irrelevant if they are substituted by gains in human capital (van den Bergh and Antal 2014). Another index often used to measure progress is the Human Development Index (HDI). The IDH is an indicator that combines life expectation, the number of years in formal education, and GDP per capita. The problem with the HDI is that it does not have any environmental dimension. Arrow et al. (2012) propose another way to measure sustainability in terms of the capacity to provide well being to future generations. They provide a model and empirical estimations of wealth in several countries. They incorporate population growth, technological change, human capital and environmental quality in their measurement of " a comprehensive measure of wealth." Other alternatives to measure progress are happiness or subjective satisfaction indices (Helliwell et al. 2016), or, as proposed by Jakob y Edenhofer (2014) a "dashboard of welfare indicators" as the Sustainable Development Indicators. The problem in this latter case is that, as stated by Fleurbaey and Blanchet (2013), the difficulty in measuring welfare is the multiplicity of indicators. There is no agreement on how social progress can be measured.

Decoupling: Previous Evidence

Beyond any definition of words, there are studies dealing with indicators to actually measure how GDP and carbon emissions decouple. To date, two of them are the most employed. One is the decoupling factor introduced in OECD (2002), defined by the rate of growth of emissions' intensity (emissions/GDP). It states that there is decoupling if emissions' intensity decreases. Unfortunately, it has clear limitations. Decoupling is only associated to a reduction in emissions' intensity, but that scenario can coexist with emissions increasing while the economy is expanding and with emissions decreasing but economic activity falling. The second indicator was introduced by Tapio (2005) and is defined as an emissions-to-economic activity elasticity (rate of emissions' change/rate of GDP change). Depending on the value of this elasticity, there are several types of decoupling scenarios, whose description is the main contribution of Tapio (2005).[2]

Decoupling indicators have been used in several studies to analyze the link between energy, environment and economy. For example, Lu et al. (2007) calculate decoupling in Germany, Taiwan, South Korea and Japan on a yearly base between 1990 and 2003 using the OECD indicator. They find coupling between environmental pressure (transportation CO_2 emissions and energy demand) and GDP except for several years in the first two countries. Freitas and Kaneko (2011), using the same indicator, examine the case of Brazil from 1980 to 2009 and uncover substantial separation between economic activity and CO_2 emissions from energy consumption. Conrad and Cassar (2014) calculate the OECD indicator for several endpoints in the small island of Malta and uncover relative decoupling for greenhouse gases from 1995 to 2011. Gupta (2015) uses that same index to study decoupling for several environmental (not only carbon emissions) endpoints in OECD countries.

Ren and Hu (2012) find different degrees of decoupling for the Chinese nonferrous metals industry in the period 1996–2008 using the Tapio (2005) decoupling index. Zhang and Wang (2013) employ it for decoupling between CO_2 emissions of the whole industry and primary, secondary and tertiary industries in a province of

[2] A third measure of decoupling was introduced by Lu et al. (2011) and employed by Wang et al. (2013). Its formula includes, in addition to GDP growth, the emissions' intensity decreasing rate. The three indices can be compared and, in fact, as shown in Conte (2016), Lu et al. (2011) and Tapio (2005) indicators are one a linear transformation of the other.

China (Jiangsu) from 1995 to 2009. A similar analysis is done by Wang and Yang (2015) for carbon emissions in the Beijing–Tianjin–Hebi economic band. Wang et al. (2013) using decoupling indicators for materials use, energy use and SO_2 in China, Russia, Japan and the USA during the 2000–2007 period, conclude that decoupling was stronger in the two OECD nations than in the two BRIC countries because of their different development stages. There are more analysis of this type for different sectors, cities, regions, nations and groups of countries.

In a less academic vein, several think tanks and international agencies evaluate if there is decoupling at the world and at the country level. They assess decoupling without using indicators but by simply looking at the rate of growth of carbon emissions and the rate of growth of GDP. Under this stream, the International Energy Agency, for example, concludes that carbon dioxide global emissions generated by the energy sector have decoupled from the world GDP since those emissions stayed basically stable in the last three years while GDP increased at a 3% rate approximately (IEA 2016). In addition, think tanks as World Resources Institute (WRI 2016) and Carbon Brief (2016) have compared CO_2 emissions and GDP of several countries and conclude that there was green growth (the equivalent of strong decoupling: GDP increases while carbon emissions decrease) for several of them between 2000 and 2013. More precisely, WRI uses CO_2 territorial emissions from the BP Statistical Review of World Energy and GDP (dollars of 2009) from the World Development Indicators for 67 countries. They find that 31% (= 21/67) of the countries in their dataset decreased their emissions between 2000 and 2013 and expanded economically during those years.

For the same period, Carbon Brief (2016) broadened the sample by using production generated CO_2 data from Carbon Dioxide Information Analysis Center (CDIAC) and GDP in each countries' local currency for 181 nations and consumption CO_2 emissions for the same source, which was available for 118 countries.[3] They do so because since it is often argued that developed countries decrease territorial emissions and increase consumption ones, it may happen that decoupling is different when considering consumption and not only production emissions. Peters et al. (2011), for example, show some evidence that rich countries are generally carbon importers (the carbon embodied in the goods they consume is larger than the one of the goods they produce) and the other way around for developing countries. Their conclusions are summarized in Fig. 1. Argentina, for example, is one of the nations that are carbon exporters.

Making that distinction between production and consumption emissions, Carbon Brief (2016) finds that 19% (=35/181) of nations increase GDP while they decrease territorial emissions, and 18% (=21/118) attain green growth when considering consumption emissions. Hence, even if developed countries are carbon importers

[3]Less countries keep track of carbon emissions from consumption in part due to the fact that inventories that have to be submitted to the United Nations Framework Convention on Climate Change are production-based.

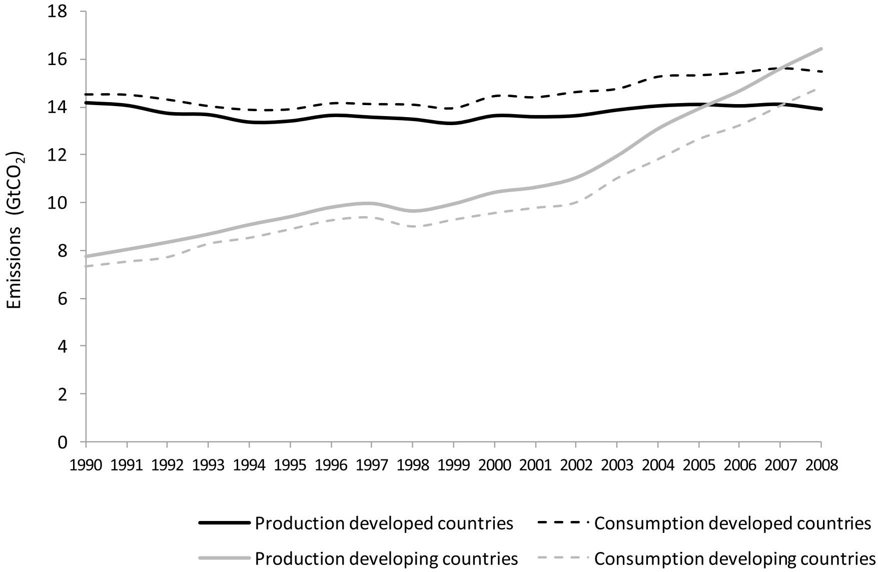


Fig. 1 Consumption and territorial CO_2 emissions in developed and developing countries *Source* Own elaboration based on data in Peters et al. (2011). *Note* Developed countries are those that belong to Annex B of the Kyoto Protocol

(consume more carbon than the one included in what they produce) and developing countries are generally carbon exporters, there is no much difference in the decoupling behavior considering one source of emission or the other.

The question is if green growth is happening and where, but also if a ranking of such decoupling results can be established. The literature on growth and environment centers on the likelihood of a desirable link between economy and the environment; the studies on decoupling indicators stress the types of decoupling they encounter, while the non-academic assessments on decoupling mainly signal those countries that are capable to increase their GDP while decreasing their carbon emissions but do not use indicators. The main innovation of this chapter is to show two decoupling rankings for countries in the world using a decoupling indicator. Instead of discussing which country fits within each type of decoupling pattern, it shows two rankings. Both balance the economy and the environment, but when there is conflict among those two goals, one of them (Ordering I) gives priority to economic growth while the other (Ordering II) prioritizes the environment. The data used for each country come from the World Bank Indicators database, for the 1990–2012 period: more precisely, GDP PPP (constant 2011 international $) and greenhouse gas emissions (kt of CO_2 equivalent). The year 1990 was chosen as the base because it was only in 1992 that the United Nations Framework Convention on Climate Change was signed, and 2012 is the last year for which total greenhouse gases information is almost complete for most countries in the world (if a most recent date is selected, the number of nations that can be included in the analysis decreases significantly).

Decoupling: Concepts and Indicators

The first decoupling indicator introduced in the literature was the one by OECD (2002, p. 19):

$$D_o = 1 - \frac{\frac{E_n}{GDP_n}}{\frac{E_o}{GDP_o}} \tag{1}$$

where E is emissions, GDP is gross domestic product, and the subscripts ($_o$ and $_n$) indicate the beginning and the end of the period respectively. It is straightforward to write D_o as:

$$D_o = -t \tag{2}$$

where t is the growth rate of emissions' intensity:

$$t = \frac{\frac{E_n}{GDP_n} - \frac{E_o}{GDP_o}}{\frac{E_o}{GDP_o}} = \frac{\frac{E_n}{GDP_n}}{\frac{E_o}{GDP_o}} - 1 \tag{3}$$

Then, according to this first indicator, when $D_0 > 0$, there is decoupling because emissions' intensity decreases ($t < 0$). On the other side, when $D_0 \leq 0$, there is no decoupling ($t \geq 0$). Hence, for this indicator, decoupling is synonymous of decreasing emissions' intensity.

Tapio (2005) introduces a decoupling index that refers to the changes in emissions to changes in the economic activity. More precisely:

$$D_\varepsilon = \frac{e}{g} \tag{4}$$

where e is emissions' growth, described as:

$$e = \frac{E_n - E_o}{E_o} = \frac{E_n}{E_o} - 1 \tag{5}$$

and g is the rate of growth of economic activity (usually proxied by the gross domestic product, GDP), characterized as:

$$g = \frac{GDP_n - GDP_o}{GDP_o} \tag{6}$$

According to Tapio (2005, p. 139), there are eight "logical possibilities" (or concepts) depending on the values of D_ε (and e and g). Coupling refers to the situation where D_ε is close to 1 (that is equivalent to saying $e \cong g$). When D_ε departs from 1, there is decoupling. If $D_\varepsilon < 0$ strong decoupling occurs (this means that e and g have opposite signs), if $0 < D_\varepsilon < 1$ decoupling is weak (this implies that e and g have the same sign), and if $D_\varepsilon > 1$, it is just decoupling (and, again e and g have the same sign since $D_\varepsilon > 0$). In the latter case, when both emissions and economy change in the same direction, if they increase this is called "expansive," and when both variables decrease, it is "recessive." Hence, the denomination "expansive" or "recessive" does not come from the value of $D_\varepsilon > 1$, but from the sign of g. The label "negative" is used in all cases when emissions' intensity increases.

To summarize, there are six relevant cases if we discard the very unlikely occurrences in which emissions, GDP and/or emissions' intensity rates of change are zero. Table 1 describes those six scenarios and allows analyzing a couple of interesting features. First, as it is clear from columns 4 and 5, the different indicators have their own values to designate the different kinds of possible coupling/decoupling between emissions and GDP. There are cases for which according to OECD (2002) there is no decoupling (Rows 3, 5 and 6 of Table 1), and there is decoupling for the Tapio (2005) index. Second, neither emissions' intensity decreases nor decoupling (separation between emissions and GDP) are good per se if there are assessed together with the objective of reducing greenhouse gases. It can happen that emissions separate from product while emissions increase (separation of both variables and $e > 0$ in Rows 2, 3, and 6 of Table 1). And, it can perfectly occur that emissions' intensity diminishes at the same time that emissions augment (Row 5 of Table 1, with $t < 0$ and $e > 0$).

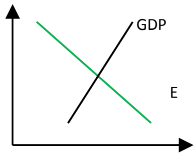
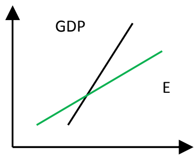
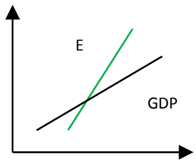
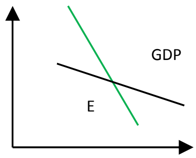
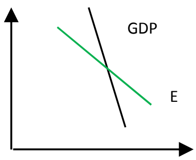
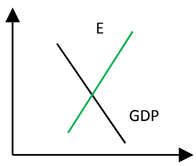
Qualifying Decoupling: From Best to Worst Cases

Decoupling cases can be qualified. There is no doubt that the best alternative is strong decoupling, since the economy grows while emissions decrease. Similarly, the worst possible scenario is the one in which GDP decreases and carbon emissions increase. However, if there is conflict and one of the dimensions improves (i.e., or economy increases or emissions decrease), and it is the other way around for the other variable (while GDP increases, emissions increase or while emissions decrease GDP decreases, for example), decoupling cases can still be ranked from best to worse according to two value judgments: prioritize economic growth and put in the second place the environment, or the other way around.

In Ordering I priority is given to the economy, weak decoupling (GDP increases and emissions increase less than GDP) is considered better than recessive decoupling (GDP decreases and emissions decrease more than GDP), but it is the other way around for Ordering II.

More precisely, as a result of Ordering I the order is: strong, weak, expansive negative, recessive, weak negative and strong negative decoupling. For the other

Table 1 Relevant coupling/decoupling cases

e	g	t	$D_o = -t$	$D_\varepsilon = \frac{e}{g}$	Emissions and GDP along time*
–	+	–	$D_o > 0$ Decoupling	$D_\varepsilon < 0$ Strong decoupling	
+	+	–	$D_o > 0$ Decoupling	$0 < D_\varepsilon < 1$ Weak decoupling	
+	+	+	$D_o < 0$ Non Decoupling	$D_\varepsilon > 1$ Expansive negative decoupling	
–	–	–	$D_o > 0$ Decoupling	$D_\varepsilon > 1$ Recessive decoupling	
–	–	+	$D_o < 0$ Non Decoupling	$0 < D_\varepsilon < 1$ Weak negative decoupling	
+	–	+	$D_o < 0$ Non Decoupling	$D_\varepsilon < 0$ Strong negative decoupling	

Source Own elaboration
Note e, g and t are the rates of growth of emissions, GDP and emissions' intensity (emissions/GDP)
*GDP and emissions are considered linear along time only for illustration purposes. The x-axis of the graphs corresponds to time

Table 2 Differences between the two orderings

Order I (priority economy)	Order II (priority environment)
Strong decoupling	Strong decoupling
Weak decoupling	Recessive decoupling
Expansive negative decoupling	Weak negative decoupling
Recessive decoupling	Weak decoupling
Weak negative decoupling	Expansive negative decoupling
Strong negative decoupling	Strong negative decoupling

Source Own elaboration based on Table 1

type of ordering (Ordering II), priority is given to the environment. In that case, the ranking would be: strong, recessive, weak negative, weak, expansive negative and strong negative decoupling. Table 2 shows both rankings: the one that favors economics (Ordering I) and the one that prioritizes the environment (Ordering II).

Types of Decoupling Depending on Some of Countries' Characteristics

With actual data, after calculating the rate of growth of emissions and of GDP (in constant terms) for each country for which there is data available, Ordering I can be made in two steps[4]: (1) Separate countries that grow of those that "degrowth"; and, (2) For the former (g > 0), the smaller the D_{ε} the greater the decoupling effect and the other way around for countries whose economy decline (g < 0).

As Table 3 shows, 28% of all countries for which there is available data followed the path of green growth (expanding the economy with less greenhouse emissions). In addition, there are 49% nations that decoupled weakly for the whole period: They grew and their emissions increased less than their GDP and only 21% of countries that behaved "wrongfully" (grew emitting more carbon). Table 3 also shows that the link between economy and nature has been more adequate considering Ordering I for the 2000s than in the 90s (82 versus 56% of countries under the strong and weak decoupling scenarios). It is also clear that few nations (3 of 149, namely Tajikistan, Georgia and Ukraine) saw their economy contract between 1990 and 2012. Of the countries that strongly decouple, 62% belong to Europe and Central Asia and those under the expansive negative scenario (the worst for those nations whose GDP increases, under Ordering I) are in sub-Saharan Africa.

Table 4 shows countries organized by decoupling case considering their corresponding World Bank income classification. Even if causality cannot be established, when analyzing the different decoupling degrees between 1990 and 2012 for countries that grow, considering their income level, it becomes clear that nations with

[4]It is not enough to use the value of the decoupling indicator. It has to be combined with the rate of growth of GDP (g).

Table 3 Countries in the different decoupling scenarios

		Decoupling case	1990–2000	(%)	2000–2012	(%)	1990–2012	(%)
g > 0	e < 0, t < 0	Strong	32	21	35	22	42	28
	e > 0, t < 0	Weak	54	35	97	60	73	49
	e > 0, t > 0	Expansive negative	49	32	28	17	31	21
g < 0	e < 0, t < 0	Recessive	10	7	0	0	3	2
	e < 0, t > 0	Weak negative	5	3	0	0	0	0
	e > 0, t > 0	Strong negative	3	2	1	1	0	0
		Number of countries	153		161		149	

Source Own elaboration
Note GDP, PPP (constant 2011 international $) and Greenhouse gas emissions (kt of CO_2 equivalent). Both data from World Bank Development Indicators Database. *g*, *e* and *t* denote the rate of growth of GDP, emissions, and emissions intensity (Emissions/GDP), respectively

Table 4 Countries by decoupling behavior and income

Decoupling/income low	Lower-middle	Upper-middle	High		All countries
1990 a 2012					
Strong	1	8	13	18	40
Weak	10	24	20	19	73
Expansive negative	12	6	8	4	30
Recessive	0	3	0	0	3
Weak negative	0	0	0	0	0
Strong negative	0	0	0	0	0
Number of countries	23	41	41	41	146

Source Own elaboration
Note GDP, PPP (constant 2011 international $) and greenhouse gas emissions (kt of CO_2 equivalent). Both data are taken from the World Bank Development Indicators Database. *g*, *e* and *t* denote the rate of growth of GDP, emissions, and emissions intensity (Emissions/GDP), respectively. The number of countries differs from Table 3 because three nations that have GDP and GHG information and so are assigned a decoupling type, are not classified by income by the World Bank: Central African Republic, Congo Democratic Republic and Cote d'Ivoire

higher income levels have been able to strongly decouple carbon territorial emissions from production (44% of high-income nations), but this was not the case of low-income nations (only 4% of them). The contrary occur for less favorable cases as expansive negative decoupling (only 10% of high-income countries and 52% of low income ones). Another way to assess the same effect is that of those nations that are under the best scenario (strong decoupling) 45% have high incomes while only 3% have low income levels.

Around 70% of the countries that strongly decoupled GHG emissions and GDP between 1990 and 2012 reduced the industrial sector share of their economies, and 78% increased the participation of the value added of services. Even if those percentages are high, they also show that GHG-GDP decoupling is feasible in countries with expanding industrial activity. Figure 2 illustrates this point. For example, strong decoupling occurs in the Russia Federation, where the participation of industry

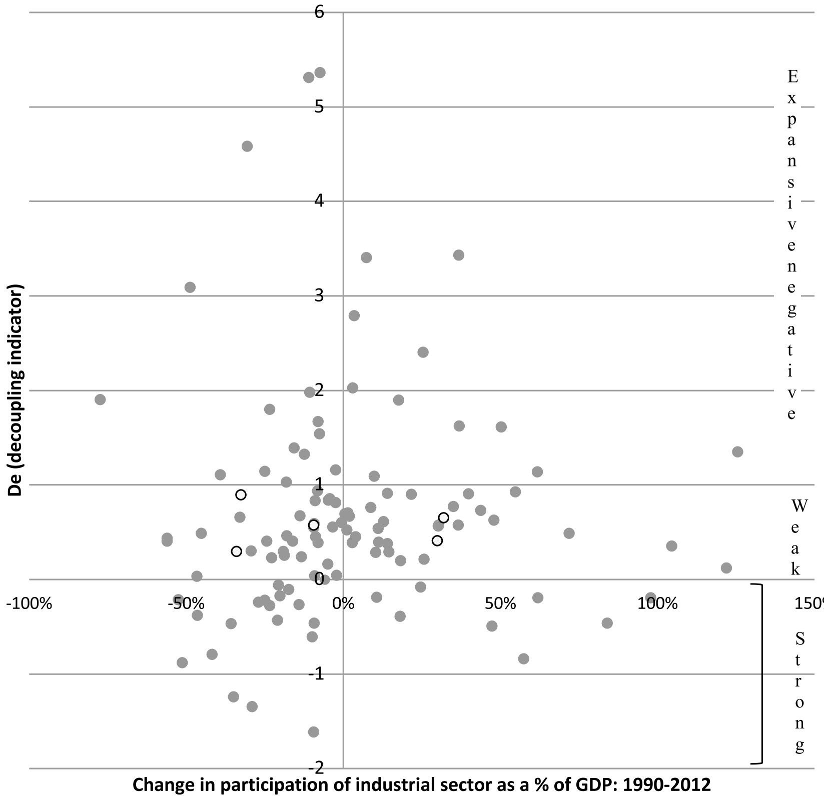


Fig. 2 Decoupling indicator and industrial activity. *Source* Own elaboration. *Note* The countries in this figure are those whose GDP increases from 1990 to 2012, expect for some particular cases as Congo, Dem. Rep., Kyrgyz Republic, Guinea-Bissau, Zimbabwe, which are not included since they have much higher decoupling indicators and so cannot be easily visualized in this figure. The red dot corresponds to Argentina, and the light dots correspond to several of the main Latin American countries: Ecuador and Mexico on the right of the y-axis and Brazil, Chile, Colombia and Uruguay on the left of the y-axis (each one can be identified with the De later reported on Table 5 in this document)

value added (as % of GDP) decreased 35%, but also in Indonesia where that sector increased its contribution to GDP in 11%. Most countries in Latin America (68% of them) weakly decouple emissions from GDP, but not all them have evolved in the same way in terms of their economic structure. As is shown on Fig. 2, in Mexico and Ecuador the share of industry in national value added has increased from 1990 to 2012, while the opposite is true for Argentina, Brazil, Chile, Colombia and Uruguay.

Countries According to Their Decoupling Ranking

Once a decoupling indicator is calculated for each nation, a rank can be assigned according to the two orderings defined above. Table 5 shows each country with its corresponding indicator and hierarchy according to both rankings (from the best to the worst decoupling scenario), for the 1990–2012 period.[5]

Table 5 shows that since there are only three nations (Tajikistan, Georgia and Ukraine) that changed their order because they correspond to cases of recessive decoupling, the correlation among orderings is high (0.94). Hence, even if conceptually, the two orderings are quite different, for these specific data, they rank countries in a similar way.

The Case of Argentina

Argentina has had a significant participation in climate summits over time, and a considerable number of Argentine scientists have been part of the Convention's technical body (the IPCC). There is *expertise* in the country regarding the preparation of inventories and climate studies (see, for example, Barros and Camilioni 2017). Several climate change impacts have been assessed and have to do with the retreat of the glaciers of the Andean mountains, the increase in the frequency of the extreme precipitations (and therefore, of the floods) in the East and Central regions, water stress due to the increase in temperature in the North and West, the increase in sea level affecting the maritime coast and the coast of the Río de la Plata, etc. A possible water crisis is also expected in several provinces of Cuyo and Comahue (MAyDS 2017).

Argentina has been presenting inventories of its greenhouse gases over the years. It has three national communications sent to the UNFCCC (1997 and its revision in 1999, 2008 and 2015) and two biannual emissions reports (2015 and 2017). The

[5]Note that there are some countries for which the calculated decoupling indicator is higher than for the rest. This is particularly the case for Congo Dem. Rep., Kyrgyz Republic or Zimbabwe. As noted by Tarabusi and Guarini (2018), this is a characteristic of the decouplingindicator we use: it is not bounded by 1. More precisely, the elasticity is high for these countries as the three ones that belong to our sample and have decoupling indicators above 10 in absolute value. Their particularity is that they have a very low GDP rate of growth for the period studied.

Table 5 Countries with rankings according to the two orderings: 1990–2012

Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II
Congo, Dem. Rep.	−26.05	1	1	Fiji	−0.06	38	38	Cyprus	0.44	75	78	Guatemala	0.91	112	115
Kyrgyz Republic	−10.77	2	2	Luxembourg	−0.03	39	39	Bahrain	0.45	76	79	El Salvador	0.91	113	116
Cote d'Ivoire	−1.61	3	3	Ireland	−0.03	40	40	Guinea	0.45	77	80	Mauritania	0.93	114	117
Romania	−1.35	4	4	Kazakhstan	−0.02	41	41	Dominican Republic	0.46	78	81	Bahamas, The	0.94	115	118
Russian Federation	−1.24	5	5	Colombia	0.00	42	42	Bhutan	0.49	79	82	Canada	1.03	116	119
Iceland	−1.04	6	6	Vanuatu	0.03	43	46	Tuvalu	0.49	80	83	Togo	1.03	117	120
Bulgaria	−0.88	7	7	Uzbekistan	0.04	44	47	Swaziland	0.52	81	84	Burkina Faso	1.09	118	121
Suriname	−0.84	8	8	Cameroon	0.04	45	48	Nicaragua	0.54	82	85	Malawi	1.11	119	122
Armenia	−0.79	9	9	United States	0.05	46	49	Panama	0.54	83	86	Ghana	1.14	120	123
Czech Republic	−0.65	10	10	Turkmenistan	0.12	47	50	Philippines	0.55	84	87	Barbados	1.15	121	124
Germany	−0.63	11	11	Peru	0.14	48	51	Korea, Rep.	0.56	85	88	United Arab Emirates	1.16	122	125
Denmark	−0.61	12	12	Greece	0.15	49	52	Oman	0.56	86	89	Seychelles	1.32	123	126
Guyana	−0.49	13	13	Malaysia	0.16	50	53	Japan	0.57	87	90	Lao PDR	1.35	124	127
United Kingdom	−0.46	14	14	Puerto Rico	0.20	51	54	Lesotho	0.57	88	91	Dominica	1.39	125	128

(continued)

Table 5 (continued)

Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II
Papua New Guinea	−0.46	15	15	Bangladesh	0.21	52	55	Chile	0.57	89	92	Djibouti	1.52	126	129
Congo, Rep.	−0.46	16	16	New Zealand	0.23	53	56	Niger	0.58	90	93	St. Vincent and the Grenadines	1.54	127	130
Belarus	−0.43	17	17	Austria	0.24	54	57	Australia	0.59	91	94	Yemen, Rep.	1,61	128	131
Brunei Darussalam	−0.39	18	18	Costa Rica	0,26	55	58	Tunisia	0,60	92	95	Comoros	1.62	129	132
Macedonia, FYR	−0.38	19	19	China	0.29	56	59	Jordan	0.61	93	96	Bolivia	1.67	130	133
Italy	−0.27	20	20	Sri Lanka	0.29	57	60	Vietnam	0.63	94	97	Chad	1.80	131	134
Sweden	−0.27	21	21	Equatorial Guinea	0.29	58	61	Ecuador	0.65	95	98	Gambia, The	1.90	132	135
Paraguay	−0.24	22	22	Uruguay	0.30	59	62	Rwanda	0.66	96	99	Sudan	1.90	133	136
France	−0.24	23	23	Sierra Leone	0.30	60	63	Ethiopia	0.67	97	100	St. Lucia	1.98	134	137
Solomon Islands	−0.22	24	24	Samoa	0.30	61	64	Turkey	0.68	98	101	Mozambique	2.03	135	138
Netherlands	−0.22	25	25	Zambia	0.30	62	65	Thailand	0.70	99	102	Jamaica	2.28	136	139
Albania	−0.21	26	26	Spain	0.33	63	66	Portugal	0.71	100	103	Madagascar	2.40	137	140
Benin	−0.20	27	27	Argentina	0.33	64	67	Antigua and Barbuda	0.71	101	104	Namibia	2.79	138	141
Azerbaijan	−0.19	28	28	Uganda	0.35	65	68	Egypt, Arab Rep.	0.73	102	105	Botswana	3.09	139	142

(continued)

Table 5 (continued)

Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II	Country name	De	Order I	Order II
Indonesia	−0.19	29	29	Kenya	0.38	66	69	Israel	0.73	103	106	Senegal	3.41	140	143
Finland	−0.17	30	30	India	0.39	67	70	Algeria	0.76	104	107	Gabon	3.43	141	144
Switzerland	−0.10	31	31	Nepal	0.39	68	71	Tanzania	0.77	105	108	Central African Republic	4.59	142	145
Poland	−0.10	32	32	Honduras	0.40	69	72	Liberia	0.81	106	109	Burundi	5.31	143	146
Angola	−0.10	33	33	Iraq	0.40	70	73	Belize	0.84	107	110	Grenada	5.36	144	147
Norway	−0.08	34	34	Nigeria	0.41	71	74	Pakistan	0.84	108	111	Guinea-Bissau	8.09	145	148
Bermuda	−0.08	35	35	Venezuela, RB	0.41	72	75	Morocco	0.85	109	112	Zimbabwe	28.23	146	149
Myanmar	−0.07	36	36	Mexico	0.41	73	76	Brazil	0.89	110	113	Tajikistan	8.24	147	43
Belgium	−0.07	37	37	Hong Kong SAR, China	0.43	74	77	Mali	0.90	111	114	Georgia	2.86	148	44
												Ukraine	1.91	149	45

Source Own elaboration
Note GDP is PPP (constant 2011 international $) and Total greenhouse gas emissions (kt of CO_2 equivalent). Both data from World Bank Development Indicators Database

country is part of those that submitted their "intended nationally determined contribution" (INDC) for the pre-Paris 2015 Summit and is one of the first nations that elaborated a "nationally determined contribution" (NDC) after the Paris Agreement (PA) was signed.

Argentina presented the INDC as a fixed goal (a certain amount of emissions is committed to 2030), but its justification includes a percentage reduction of the projected emissions of a scenario without climate policies, or BAU for *business as usual*).[6] The argument used to support this choice is that this metric is the usual one for developing countries. However, that is not entirely correct. Several of our neighbors did not opt for such type of goals. For example, Chile and Uruguay chose emission intensity targets, while Brazil opted for absolute reductions anchored in the past.

The contribution of Argentina within the PA is that it commits to emit no more than 483 or 369 $MtCO_2$-e depending on receiving or not international financial assistance. This means a reduction of its aggregate emissions by 18% with respect to BAU by 2030 (i.e., 592–483/592), taking emissions without policies whose projection begins in 2005. If Argentina received financial aid to undertake more mitigation measures, total reductions would reach 37% (i.e., 592–369/592).

The text of the NDC states that Argentina's contribution is fair and ambitious considering the data of the last report of the emissions gap (UNEP 2016). The rationale is that Argentina's net emissions in 2014 are 0.7% of global GHG emissions (ie., 369/52,700 $MtCO_2e$) while the country contributes its unconditional target with a 2.8% of the reductions committed by all countries to comply with the Paris Agreement (i.e., 109/3900). For this reason, it is said that their participation in contributions is four times (0.7 * 4 = 2.8) the participation in the emissions. Another statement included in the NDC text is that the unconditional and total reductions are 0.6% and 1.3%, respectively, of the effort necessary to close the gap between the emissions foreseen for 2030 with current policies and those that are needed to reach the goal of the two degrees. However, making an account of the participation in emissions when the unconditional goals of all countries are met, Argentina's participation in 2030 would be 0.87% (483/55,500). This is more than the 0.7% that the country participated in 2014 in the total emissions, but it is the comparison that should be used to justify the fair and ambitious without using the BAU scenario. This would be the correct way if the target, as Argentinean authorities defend, is a fixed target and not one that depends on the BAU scenario.

Despite these justifications, both the unconditional INDC and the NDC of Argentina were considered insufficient by the international community. In particular, a think tank formed by several institutions of international prestige, which is dedicated to monitoring national contributions (see <www.climateactiontracker.org>), stated that, despite the improvements introduced to the goal by the new government, it is "critically insufficient."

[6]This has not always been the case. The country designed a contribution that depended on GDP in 1999 (see Barros and Conte Grand 2002).

In fact, Argentina is a country that ranks approximately at the 60th place among almost 150 nations present in the database. In fact, between 1990 and 2012, its GDP increased at an annual average rate of 4%, while emissions increased 2% annually on average (the rates of growth for the overall period are 129% and 43%, respectively). This means that Argentina is decoupling emissions in a weak (and not strong) way. Hence, if the unconditional goal is met, GHG emissions will have increased by 18% between 2005 and 2030 (i.e., 483–409/409, all in $GtCO_2$-e). Only if both types of targets are adopted (unconditional and conditional), would the Climate Action Tracker consider the goal simply insufficient since emissions would fall between 2005 and 2030 by 10% (i.e., 369–409/409).

Argentina has still a long way to go to be able to strongly decouple emissions from GDP. However, it has undertaken several steps that should lead it to a stronger decoupling. In particular, it has established specific plans to reduce emissions in all sectors,[7] Energy policies include: changes in energy efficiency; increase in renewable energy generation; increases in biofuels mixing; changes in large-scale generation as substitution of fossil fuels by natural gas. Transportation emissions' reductions plan encompass: changes in urban mobility through, for example, promotion of public transportation; efficiency improvements in freight transportation; or commercial aviation modernization. Mitigation measures in the agricultural and forestry sectors intend to increase forested areas, limit oilseeds plantation and use biomass for energy generation, among others. Industrial mitigation measures refer to recovery of waste flows, an increase in motors efficiency and the use of more efficient energy sources. In general, policies are weighted in terms of how many emissions they decrease, not in terms of the extent to which they allow decoupling. This happens because there is generally no coordinate work between economic and environment regulatory bodies, and also lack of knowledge of the usefulness of decoupling indicators follow-up.

Conclusions

As shown in this chapter, decoupling greenhouse gases from economic evolution is not favorable per se. It can perfectly happen that emissions and GDP trends separate from each other and emissions increase and/or GDP decreases. Neither augmentations in emissions nor GDP contraction can be an objective to pursue. Similarly, declines of emissions' intensity are not goals by themselves because they can be compatible with increasing emissions and/or GDP contraction.

Hence, "decoupling" as an aim has to be qualified. Orderings can be constructed trying to balance green and growth. Two rankings were constructed here using the decoupling indicator constructed by Tapio (2005). The order depends on, if when there is conflict between economy and nature, priority is given to one or the other.

The results show that around 30% of countries in the world are strongly decoupling their greenhouse gases from their economic activity considering the 1990–2012

[7]Refer to https://www.argentina.gob.ar/ambiente/sustentabilidad/planes-sectoriales.

period. This means that in the last several years their GDP increased and emissions decreased. This is the ideal decoupling state. But, there are around 50% more nations that have weakly decoupled (have increased emissions less than economy) and around 20% are in a worse situation. High-income countries tend to have high ranks of decoupling while low income ones usually are on the bottom of the list. In terms of geography, Europe and Central Asia nations are among those that are ranked better and there are many sub-Sahara African countries in the last places.

The two rankings differ for the order they assign: For example, recessive and weak negative decoupling scenarios are considered worse in Ordering I than in II because they imply "degrowth" but emissions that decrease. Since there are only three countries that followed recessive decoupling paths and no countries under the weak negative decoupling scenario, the two orderings do not depart substantially from each other, even if they are conceptually different (one favors economy and the other nature, when there is conflict).

The way the relationship between emissions' and GDP changes evolves differently for each country in the world. This link clearly depends on what and how each of them produces. Desirable decoupling (strong one) is not automatically attained, it has to be driven by both market and government policy forces (Stavins 2016). According to UNEP (2017), there are six areas with alternatives that could be cost-effective to deal with climate change: solar and wind energy, efficient appliances, efficient passenger cars, afforestation and stopping deforestation. Policies within those grounds could imply reductions that would allow fulfilling the Paris Agreement objective. Note that the relevant policies can be climate or non-climate oriented. For example, mercury standards at the US discouraged coal-fired electricity and so reduce GHG emissions. The same happens with motor vehicle standards set because of local air pollution pollutant, but whose efficiency improvement helps climate.

Argentina's climate action has considerably improved in the last few years. Nevertheless, it has only weakly decoupled its emissions from GDP. This means that from 1990 to 2012, country's emissions increase less than GDP. Argentina has compromised an absolute emissions' target at the Paris Agreement. It has also presented specific planned reductions for three sectors (energy, transportation and forestry) and mitigation options in industry and agriculture are under study. Argentina's decoupling behavior may improve in the long-run if the effort underway continues.

Acknowledgements The author thanks participants at the Workshop on Climate Change Economics at Universidad Católica Argentina (April 2018) for their comments, Augustin Shehadi for his help as a research assistant and UCEMA's library personnel for handling all the references' requests.

References

Adler MD (2012) Well-being and fair distribution: beyond cost-benefit analysis. Oxford University Press, p 656

Arrow KJ, Dasgupta P, Goulder LH, Mumford KJ, Oleson K (2012) Sustainability and the measurement of wealth. Environ Dev Econ 17:317–353

Barros V, Camilioni I (2017) Argentina y el Cambio Climático. De la Física a la Política, Eudeba

Barros V, Conte Grand M (2002) Implications of a dynamic target of GHG emissions reduction: the case of Argentina. Environ Dev Econ 7:547–569

Carbon Brief (2016) The 35 countries cutting the link between economic growth and emissions. Policy 5

Conrad E, Cassar L (2014) Decoupling economic growth and environmental degradation: reviewing progress to date in the small island state of Malta. Sustainability 6(10):6729–6750

Conte GM (2016) Carbon emission targets and decoupling indicators. Ecol Ind 67:649–656

Cosme I, Santos R, O'Neill DW (2017) Assessing the degrowth discourse: a review and analysis of academic degrowth policy proposals. J Cleaner Prod 149:321–334

Daly HE (ed) (1973) Towards a steady state economy. Freeman & Co Ltd., W. H, p 332

Dasgupta S, Laplante B, Wang H, Wheeler D (2002) Confronting the environmental Kuznets curve. J Econ Perspect 16:147–168

Dollar D, Kleineberg T, Kraay A (2013) Growth still is good for the poor. World Bank policy research working paper 6568

Dreze J, Sen A (2013) An uncertain glory: India and its contradictions. Princeton University Press, Princeton, NJ, p 434

Fleurbaey M, Blanchet D (2013) Beyond GDP. Oxford University Press, Oxford. xvi + p 306

Freitas de LC, Kaneko S (2011) Decomposing the decoupling of CO_2 emissions and economic growth in Brazil. Ecol Econ 70(8):1459–1469

Georgescu-Roegen N (1971) Entropy law and the economic process. Harvard University Press, Cambridge

Grossman GM, Krueger AB (1995) Economic growth and the environment. Q J Econ 110(2):353–377

Gupta S (2015) Decoupling: a step toward sustainable development with reference to OECD countries. Int J Sustain Dev World Ecol 22(6):510–519

Hamilton K (2000) Genuine saving as a sustainability indicator. In: OECD proceedings: frameworks to measure sustainable development, pp 65–78

Helliwell JF, Huang H, Wang S (2016) The distribution of world happiness. In: World happiness report 2016 update, vol I. Sustainable Development Solutions, New York

IEA (2016). International energy agency. See https://www.iea.org/newsroom/news/2017/march/iea-finds-co2-emissions-flat-for-third-straight-year-even-as-global-economy-grew.html. Accessed 10 Sept 2018

IPCC (2014) Summary for policymakers. In: Climate change 2014: mitigation of climate change. Contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change [Edenhofer O, Pichs-Madruga R, Sokona Y, Farahani E, Kadner S, Seyboth K, Adler A, Baum I, Brunner S, Eickemeier P, Kriemann B, Savolainen J, Schlömer S, von Stechow C, Zwickel T, Minx JC (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Jacobs M (2013) Green growth. In: Falkner R (ed) Handbook of global climate and environmental policy. Wiley Blackwell, Oxford

Jakob M, Edenhofer O (2014) Green growth, degrowth, and the commons. Oxford Rev Econ Policy 30(3):447–468

Kallis G (2011) Defence of degrowth. Ecol Econ 70:873–880

Lu IJ, Lin SJ, Lewis C (2007) Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany Japan and South Korea. Energy Policy 35:3226–3235

Lu Z, Wang H, Qiang Y (2011) Decoupling indicators: quantitative relationships between resource use, waste emission and economic growth. Resour Sci 33(1):2–9 (in Chinese)

MAyDS (2017) Cuadernillo Inventario Gases de Efecto Invernadero Argentina. Ministerio de Ambiente y Desarrollo Sustentable. https://inventariogei.ambiente.gob.ar/files/inventario-nacional-gei-argentina.pdf

Martinez-Alier J, Pascual U, Vivien F-D, Zaccai E (2010) Sustainable de-growth: mapping the context, criticisms and future prospects of an emergent paradigm. Ecol Econ 69(9):1741–1747

Meadows DH, Meadows DL, Randers J (1972) The limits to growth. Universe Books, New York, NY

OECD (2002) Indicators to measure decoupling of environmental pressure from economic growth. Sustainable Development. SG/SD (2002) 1/Final. Organization for economic co-operation and development

OECD (2009) Declaration on green growth adopted at the meeting of the council at ministerial level on 25, C/MIN(2009)5/ADD1/FINAL

Peters GP, Minx JC, Weber CL, Edenhofer O (2011) Growth in emission transfers via international trade from 1990 to 2008. Proc Nat Acad Sci 108:8903–8908

Ren S, Hu Z (2012) Effects of decoupling of carbon dioxide emission by Chinese nonferrous metals industry. Energy Policy 43:407–414

Stavins RN (2016) The ever-evolving interrelationship between GDP and carbon dioxide. Environ Forum 33(4):17

Stokey NL (1998) Are there limits to growth? 39(1):1–31

Tapio P (2005) Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. Transp Policy 12(2):137–151

Tarabusi EC, Guarini G (2018) An axiomatic approach to decoupling indicators for green growth. Ecol Ind 84:515–524

UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth. United Nations Environment Program. A report of the working group on decoupling to the international resource panel

UNEP (2016) Emissions gap report 2016. United Nations Environmental Program

UNEP (2017) Emissions gap report 2017. United Nations Environmental Program

Van den Bergh JC (2011) Environment versus growth: A criticism of "degrowth" and a plea for "a-growth." Ecol Econ 70(5):881–890

Van den Bergh JC, Antal M (2014) Evaluating alternatives to GDP as measures of social welfare/progress, WWW for Europe working papers series 56

Wang H, Hashimoto S, Yue Q, Moriguchi Y, Lu Z (2013) Decoupling analysis of four selected countries: China, Russia, Japan, and the United States during 2000–2007. J Ind Ecol 17(4):618–629

Wang Z, Yang L (2015) Delinking indicators on regional industry development and carbon emissions: Beijing-Tianjin-Hebei economic band case. Ecol Ind 48:41–48

Weiss M, Cattaneo C (2017) Degrowth-Taking stock and reviewing an emerging academic paradigm. Ecol Econ 137:220–230

WRI (2016) The roads to decoupling: 21 countries Are reducing carbon emissions while growing GDP. World Resources Institute

Zhang M, Wang W (2013) Decouple indicators on the CO_2 emission-economic growth linkage: the Jiangsu Province case. Ecol Ind 32:239–244