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What Can Be Learned from “Green Growth Diagnostics” for Greening the Growth Path of China? - Conceptional Issues and Industry Evidence

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What Can Be Learned from "Green Growth Diagnostics" for Greening the Growth Path of China? Conceptional Issues and Industry Evidence

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<u>Abstract:</u>
It is evident that China's manufacturing-based growth model increasingly contradicts local, regional and global environmental imperatives. It is therefore of high importance to identify cost-efficient strategies for greening the growth path of China. On 25 May 2011 the OECD has launched a "Green Growth Strategy" and proposed a "Green Growth Diagnostics" approach to identify the binding constraints on green growth. This paper discusses the usefulness of this approach for identifying the binding constraints to green growth in general as well as for the special case of China. It is argued that the approach is best applied at the industry level after some adjustments to identify binding constraints to the 'greening' of certain industries. The workings of the approach are illustrated for the case of the Chinese energy sector.

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1. Introduction

It is evident that China's manufacturing-based growth model increasingly contradicts local, regional and global environmental imperatives. According to the Environment Performance Indicator 2010, China ranks 121 in a sample of 163 countries. China's new 12th five-year plan (2011-2015) envisions a cut of energy use and carbon dioxide emission per unit of GDP by 16% and 17%, respectively. Greening the growth path of China may be costly, with consequences for the international competitiveness of a number of industries. It is therefore of high importance to identify cost-efficient strategies for greening the growth path of China.

On 25 May 2011 the OECD has launched a "Green Growth Strategy". In OECD (2011a) a "Green Growth Diagnostics" approach is proposed which is a variant of the "growth diagnostics approach" advocated by Hausman et al. (2008), a methodology to identify the binding constraints on growth in developing economies. The main idea of this approach is taken over by the green growth diagnostics, namely that not all shortcomings and thus constraints to (green) growth are equally binding. Thus it is economically efficient to identify the most binding constraints and address these problems first. In this way one may be able to identify the policy areas and actions with the largest impact on (greening) growth while at the same time ensuring cost-benefit efficiency of potential policy instruments.

This paper will discuss the usefulness of this approach for identifying binding constraints to green growth in general as well as for the special case of China. It will be argued that the approach is best being applied not only at the economy-wide level but at the industry level. After a few modifications it can serve as a helpful instrument to identify binding constraints to a 'greening' of certain industries. The greening of the Chinese (renewable) energy sector is used to illustrate how green growth diagnostics can help to green China's economic growth.

The plan of the paper is as follows: in section 2 the green growth diagnostics approach will be introduced and discussed critically. In section 3 I will propose a green growth diagnostic for the industry level. Section 4 illustrates my suggestions with recent evidences from China. Section 5 concludes.

2. The OECD's Green Growth Diagnostics Approach

2.1. Green Growth, Sustainability and Externalities

Before discussing what green growth diagnostics is actually aiming to diagnose I will briefly review OECD's green growth concept and its relation to the concepts of sustainability and external effects. According to the main report *Towards Green Growth* "[G]reen growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD 2011b: 9). This definition brings the idea of sustainable development to mind immediately. OECD (2011b: 11) clarifies the relation between green growth and sustainability as follows:

> "Green growth has not been conceived as a replacement for sustainable development, but rather should be considered a subset of it. It is narrower in scope, entailing an

operational policy agenda that can help achieve concrete, measurable progress at the interface between the economy and the environment. It provides a strong focus on fostering the necessary conditions for innovation, investment and competition that can give rise to new sources of economic growth – consistent with resilient ecosystems."

The concept of green growth is therefore on the one hand much narrower than the sustainability concept as it concentrates on the environmental and economic pillars of the sustainable development concept but leave of the social pillar. Moreover, and if we accept this narrower focus, even in its so-called weak definition, sustainability demands to maintain the overall (global) economic and natural capital.[1] This definition is also reflected in the well-known Brundtland Report definition that the guiding principle should safeguard "…the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1997). By contrast, green growth according to the OECD strategy is everything that compromises the ability of future generations less than "business as usual". While emphasizing fostering economic growth, the OECD concept therefore requires "progress" in rather than absolute decoupling of environmental damage from economic growth – and any such progresses is understood as green growth.[2] On the other hand, however, the sustainability concept is narrower than green growth if it is understood only as a concept for inter-generational equity. Green growth needs also to take into account intra-generational equity and should not lose sight of the "needs of the present generation" as much of the environmental damage is often at the expense (and the health) of the present generation.

Since green growth is intrinsically tied to costs/expenses of present and future generations, it is may be appropriate to choose the economic concept of external effects as a point of reference for green(ing) growth.[3] Externalities simply mean one or several actors' utility is affected by actions of somebody else. As a static concept, a negative externality means that somebody harms someone else without compensation. Consequently, the economic incentives favor such behavior and lead to a misallocation of resources and thus welfare losses. As a dynamic concept, intertemporal externalities are basically reflecting the concept of sustainability. As argued by van den Bergh (2010: 2048), "…without such externalities the problem of unsustainability vanishes, unless sustainability is defined to cover resources or environmental stocks that bear no relation whatsoever to human welfare." Thus, greening growth will always imply addressing externalities. As far as intertemporal externalities are concerned, greening growth also addresses the problem of sustainability – though only partially and only as much as it gives "…rise to new sources of economic growth – consistent with resilient ecosystems."

[1] „Weak sustainability" allows for depletion of natural resources provided future generations are compensated for the loss in natural capital, e.g. by a higher stock of physical capital or technological know-how. By contrast "strong sustainability" demands to maintain the stock of natural capital. Depending on the view this can range asking to maintain a broad based "aggregate natural capital" stock to a very strict view on each subset of natural capital.

[2] See the statement of environmental NGOs (EEB 2011) who criticize that green growth is not demanding absolute decoupling.

[3] There has been an important and extensive recent debate on the relation of the concepts of externalities and sustainability and whether or not internationalization of externalities is sufficient to ensure sustainability. Major contributors to the debate in the journal *Ecological Economics* are Baumgärtner and Quaas (2010a, 2010b), Bartelmus (2010), van den Bergh (2010), Bithas (2011) and Ballet et al. (2011). I will extend on these issues when developing my adjusted green growth diagnostics in section 3.

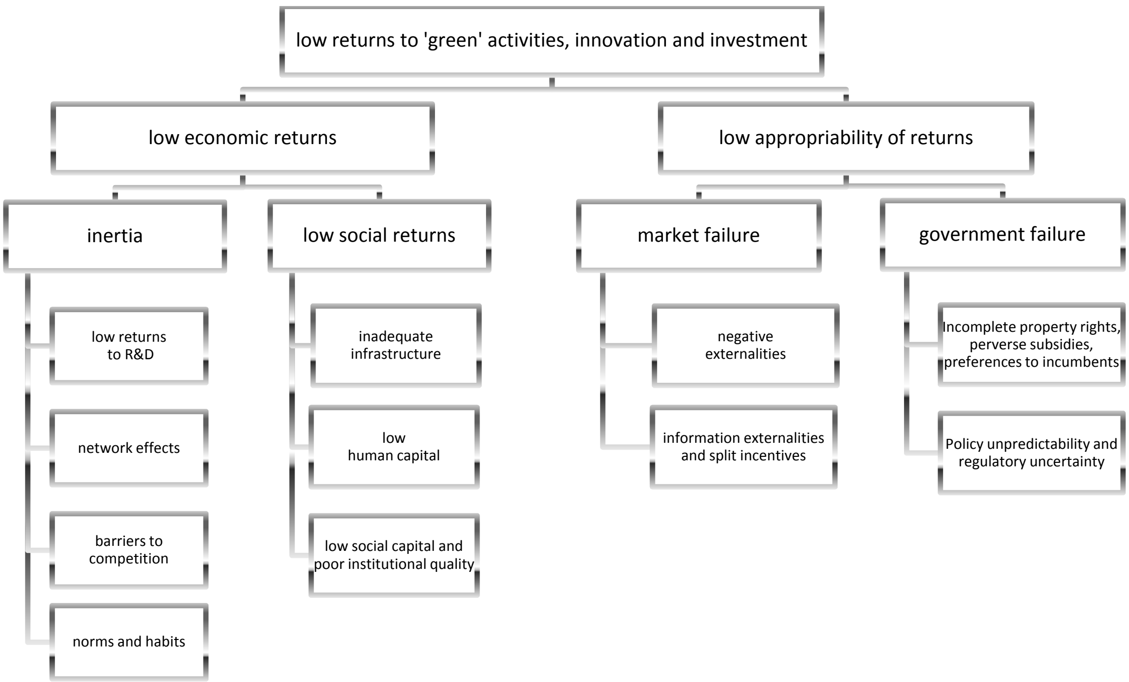
As such the concept suggests that economic growth and resilient ecosystems are not contradictions and that win-win solutions are possible, provided we can identify the right policy agenda. This idea is closely related to green economy approach launched by UNEP (2011) which is also based on the idea that achieving sustainability "rests almost entirely on getting the economy right".

2.2. Green Growth Diagnostics

Green growth diagnostics is a tool proposed by OECD (2011a) to identify binding constraints to green growth. As such – and in analogy to its role model "growth diagnostics" – it should be understood as an exercise to derive policy priorities. The green growth diagnostics approach follows the idea developed by Hausman et al. (2008) to identify binding constraints to economic growth in developing economies. This approach relies on three basic ideas: First, the resources for promoting growth are limited. Hence they should be used where the growth effect is the highest. This does not only involve economic resources but also – and in many cases even more– political resources for reforms. Second, not all growth constraints are (equally) binding. For instance, many developing countries do have bad infrastructure, low human capital, and weak governance structures, but not all of these factors must be binding constraints. If, for instance, corruption holds a country back, investment in human capital may eventually result in higher migration rather than higher growth. Thus the binding constraints need to be identified. Thus, growth diagnostics should help to devise a growth strategy with a clear sense of priorities. Third, and as a consequence, the approach argues strongly in favor of a country-specific policy approach as constraints are not equally binding under all circumstance and at all levels of development.

Can this approach turned into a useful tool for greening (national) growth? Figure 1 presents the green growth diagnostics approach as it is advocated by OECD (2011a):

Figure 1: OECD (2011) Green Growth Diagnostics



The OECD approach identifies two causes of “low returns to ‘green’ activities, innovation and investment” and thus too low activities in these areas as compared to a socially optimal level. The first reason identified is that these returns are indeed low - either because of low social returns or because of some kind of inertia. If this is not the case, low appropriability of these returns is identified as the problem - either because of government failure (such as incomplete property rights) or because of market failures, in particular negative externalities.

2.2. A Critical Evaluation of Green Growth Diagnostics

An important contribution of the proposed diagnostics model is the breadth of the green growth constraints listed in Figure 1. In particular, it is very valuable that the list of green growth constraints is extended above the usual reference given to negative (environmental) externalities by pointing to the possibility that path dependencies of R&D activities, slow changing norms and values, and inadequate complimentary resources, such as inadequate infrastructure and low human capital can hold back green growth. And if the figure is read in the spirit of the growth diagnostics approach, the authors seem to conjecture that this could happen even if one would correct for negative environmental externalities e.g. by internalizing them into prices. That would mean that internalization of external effects is at best a necessary but not a sufficient condition for greening economic growth. This is a very important and valuable addition to both, the theory of externalities and the sustainability approach and I will elaborate later more on this.

In close relation to this, and again in the spirit of growth diagnostics, the approach recognizes that a country-by country approach is needed. The OECD highlights the crucial role of development level as witnessed by the following quote:

> “The importance of constraints to green growth will vary according to level of development, socio-economic context, and existing economic and environmental policy settings. Low human capital or inadequate infrastructure will tend to be associated with lower levels of economic development (though not exclusively). Rectifying these constraints will be of high priority and perhaps a precondition to resolving many other constraints. Where human capital is relatively abundant and infrastructure relatively well-supplied, the focus should first be on resolving government and market failure.” (OECD 2011a: 6)

While I believe that the approach makes valuable contributions, my first experience with it is, however, that the approach – at least as it has been presented to the public – faces some difficulties when applied in practice. Recall that the main idea of the (green) growth diagnostics approach is to identify binding constraints to (green) growth. This way policy makers should be enabled to identify the policy areas and actions with the largest impact on (greening) growth while at the same time ensuring cost-benefit efficiency of potential policy instruments. I have three points here: first, the potential for greening growth differs greatly across industries. Thus, focusing these industries should already be part of the green growth diagnostics exercise. Second, identifying green activity constraints cannot be reasonably done at the macro-economic level but only at the level of industry and/or certain environmental challenges (e.g. CO_2 emissions). Third, the present organization of the decision tree may not be optimal for identify policy priorities depending on specific country circumstance.

With respect to the first issue, the approach focuses on green(ing) national economic growth. If it is overall growth that is supposed to be "greened" one must use a composite index of the **overall** environmental impact of **all** economic activities within a country. Clearly, the OECD approach addresses national policy makers, thus its focus is national and there is nothing wrong with it as a target. However, at a national level – and depending on the national development level, it is well known that the constraints for green(-er) growth vary considerably across industries. Green(-ing) growth in a well-targeted way must recognize this and should therefore focus on industries as it is well documented they vary drastically in their environmental impact. When identifying binding constraints on green growth it would therefore best to be targeted at industries with the highest potential for greening growth. As such, going through the growth diagnostics tree would then only be the second step after identifying the problem sectors of the economy. For example, in an important recent empirical contribution Muller, Mendelsohn and Nordhaus (2011) have developed a methodology to calculate "gross environmental damage" (GED) of sectors and industries, both in absolute values as well as in percent of value added. It is striking that the GED in some industries even exceeds the value added produced in that industry. Table 1, reproduced from their paper, gives an impression.

Table 1: Gross External Damages (GED) in US-$ and in Per Cent of Value Added by Industry in the USA in the Year 2000

Industry	GED/VA	GED
Solid waste combustion and incineration	6.72	4.9
Petroleum-fired electric power generation	5.13	1.8
Sewage treatment facilities	4.69	2.1
Coal-fired electric power generation	2.20	53.4
Dimension stone mining and quarrying	1.89	0.5
Marinas	1.51	2.2
Other petroleum and coal product manufacturing	1.35	0.7
Steam and air conditioning supply	1.02	0.3
Water transportation	1.00	7.7
Sugarcane mills	0.70	0.3
Carbon black manufacturing	0.70	0.4
Livestock production	0.56	14.8
Highway, street, and bridge construction	0.37	13.0
Crop production	0.34	15.3
Food service contractors	0.34	4.2
Petroleum refineries	0.18	4.9
Truck transportation	0.10	9.2

Notes: GED in $ billion per year, 2000 prices. Industries included in Table 2 have either a GED/VA ratio above 45 percent or a GED above $4 billion/year.

Source: Muller et al. (2011: 1655).

Secondly, green growth diagnostics can only be meaningful performed when conducted at the industry level or at the level of certain environmental challenges, e.g. pollutants. It is very clear that each industry will face very different binding constraints. A similar point can be made for certain pollutants. Here the empirical relation between development levels and environmental damage by category has been extensively documented by estimates of the so-called "Environmental Kuznets Curve" (EKC). Whereas, for example, sulphur dioxide (SO_2) emissions tend to decrease after surpassing a middle per capita income level of round about 5-6000 US-$, the search for an EKC for CO_2 has only recently brought results for very high per-capita levels (Frankel and Rose, 2004; Frankel, 2009). With a focus of the green growth diagnostics exercise on certain pollutants, rather than on greener growth per se it is clearer and easier to identify binding constraints at a national level with an explicit consideration of the development level. In fact, OECD (2011b: 129) is providing such an analysis in Table 5.1. But it is striking that here almost all constraints listed in the decision tree are listed again as constraints for green growth with respect to climate change.

This brings me to my third point, the organization of the decision tree itself. To start with, consider the first decision node in the Hausman et al. (2008) growth diagnostics decision tree. The distinction between the two sides of the decision tree is clear-cut: If you have a good project with positive returns it could be hold back by a lack of finance – hence finance would be the binding constraint. If finance is not binding, e.g. signaled by low real interest rates, than low rates of investments may be rooted in low returns to these investments – for a variety of reasons that have to be explored in later steps. In OECD's green growth diagnostics, however, this is not that univocal. Even OECD (2011a: 6) acknowledges that "[T]he categories of constraints described in Figure 1 are not entirely separable". But the question is then whether the categories chosen are really useful for the proposed diagnostics exercise or whether the whole exercise is then useful at all. If not, the approach in its presented form would in this case only result in just another collection of environmental indicators[4] rather than assisting in identifying binding constraints.

3. A Green Growth Diagnostics Approach for Eco-Innovation

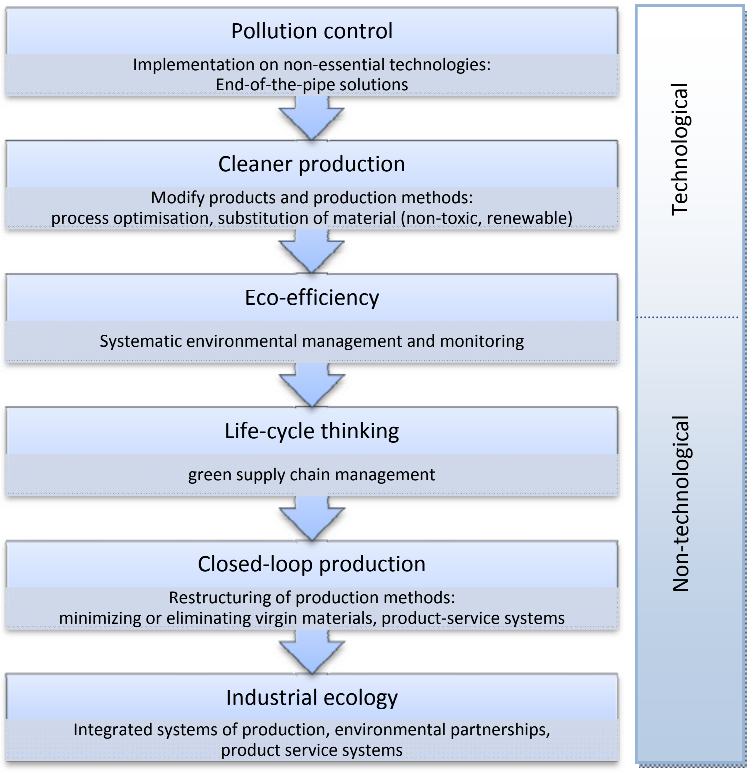
In the following I will modify the green growth diagnostics with a view on providing an instrument for identifying binding constraints with respect to environmental challenges and industries rather than focusing on the macro level. To cover both, the industry level as well as the level of certain environmental challenges it may be useful to link the growth diagnostics with the concept of eco-innovation that has been promoted in recent times and figured prominently in the green growth debate.

3.1. Greening Growth by Means of Eco-Innovation

OECD (2009: 40), based on various sources suggests, that eco-innovation can be described as "the implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangement which, with or without intent, lead to environmental improvements compared to relevant alternatives." The eco-innovation concept is rather broad and covers everything from technological improvement in resource efficiency to societal innovations in mobility concept and work-life balance. Figure 2 illustrates the concepts based on OECD (2009):

[4] In fact, in Chapter 4 of *Towards Green Growth* (OECD 2011b) a set of indicators based on the green growth diagnostics exercise is introduced.

Figure 2: Levels of Eco-innovation



Source: Based on OECD (2009: 37, 47)

Pollution control is addressing the product level, while "cleaner production" involves production processes, too. Both concepts are technological in nature while the other concepts are increasingly relying on non-technological organizational and societal innovations, including changes in values and norms. In particular, product-service systems (PSS) that focus on delivering the product functionality rather than the product itself can change the way and efficiency we use resources drastically. Instead of PCs with huge memory storage cloud computing can reduce resource use. The automobile industry is increasingly – at least partly – focusing on supplying mobility. Leasing systems are another example where the customer is provided with the product service but the ownership of the product is retained by the producer – thus allowing for a (more) closed-loop production. Mobile phones may be here a case in point given the value and scarcity of the input materials, such as gold and rare earths – not to mention the environmental health damaging effects of informal recycling of electronic waste in several poor regions of the world. It is clear that the more we depart from the purely technological point of view and adopt a systems perspective, the more important become inertia factors as a constraint to green(er) growth. Conversely, changing societal values and norms and more openness to new innovations types, organizational structures and (R&D-) networks can reduce inertia and thus promote effective eco-innovation.

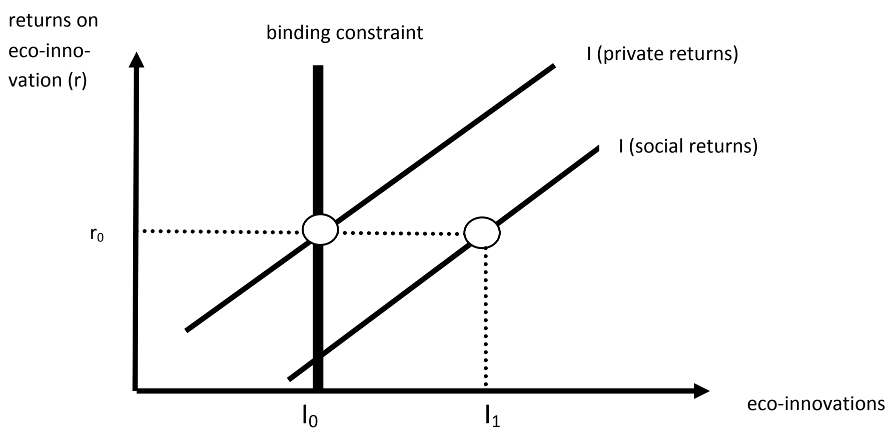
Going beyond the narrow limits of technological eco-innovations and alleviating binding behavioral and societal constraints have therefore the potential to unleash enormous positive environmental effects. The task of green growth diagnostics may thus be to identify to what extent these factors are indeed binding constraints for a certain industry at various levels of eco-innovations – and eventually address them.

3.2. The Green Growth Diagnostics Decision Tree for Eco-Innovation

To redesign the decision tree I start from the observation that eco-innovation for different pollutants and/or environmental challenges as well as different industries have their own greening problem that needs to be diagnosed separately. The green growth diagnostics should therefore identify what holds back eco-innovations that could contribute to less environment impact of either a particular industry or with respect to a certain pollutant or environmental challenges. The researcher would therefore also have to make clear the level of eco-innovation he or she is addressing.

The second step then involves setting up the green growth diagnostics in a way that it helps the researcher to identify the binding constraint. To do so, consider the following set-up: Assume a world without governance and market failure (e.g. because the latter would have been properly addressed). Even in this world, a lack of complimentary resources, like infrastructure, human capital or access to technology, could hold back eco-innovation. Or to put it the other way around: Addressing market failures or assigning property rights would hardly bring any greening of innovation if these complimentary resources are lacking. The point is best illustrated with pollutants using the EKZ. GDP per capita is highly correlated with issues like infrastructure, human capital endowment as well as access to “green technology”. One may argue that these factors may be the most binding in poor countries depending on the environmental challenge under consideration – and in fact, this seem to be the position of OECD (2011). The idea could therefore simply be illustrated as a constraint on eco-investment:

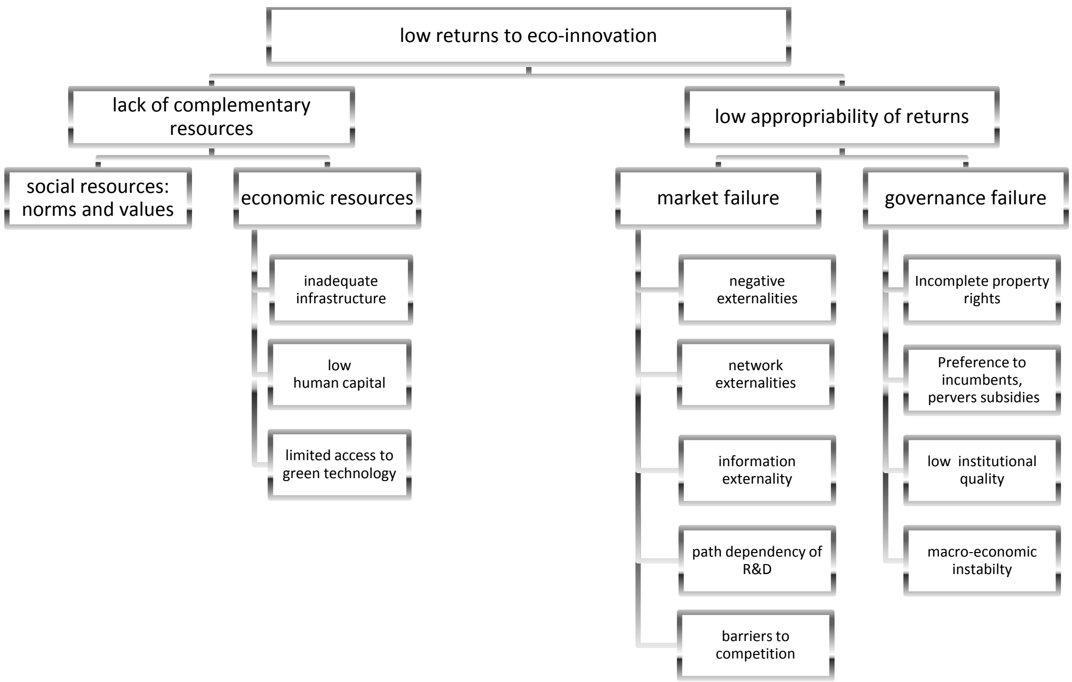
Figure 3: Lack of complementary resources as a binding constraint on eco-investments



The upward sloping investment functions signals that eco-innovation is positively related to the privately appropriable returns on these innovations. However, we assume that social returns are higher than private returns. Hence, without internalizing the externalities, at r_0 there will be too little eco-innovations (I_0). Effective internalization would in principle boost eco-innovation to the socially desirable level I_1. If however, infrastructure, human capital and lack of access to green technology are binding, eco-innovations would remain at the low level I_0. A similar point could be made for social resources, namely norms and values. They can be viewed as a behavior that acts against eco-innovation as such that it result into non-acceptance of eco-product innovations and a continuation of traditional behavior even after proper internalization of externalities, e.g. the consumption of traditional fuels would not react to increasing fuel prices, or if less resource-intensive products, processes, PSSs, organizations and institutions would not be accepted. Consequently, eco-innovations would be effectively constrained.

If we therefore reorganize the OECD growth diagnostics along these lines, we can obtain a much clearer distinction between the left hand side (LHS) and the right hand side (RHS) of the diagnostics tree and thereby in fact generate a decision tree.[5] I will therefore regroup all constraints mentioned by OECD (2011) on the left-hand side – except norms and habits, infrastructure and low human capital - to the right-hand side. I do so because partly they are indeed market failure (e.g. network effects, inertia in R&D, barriers to competition) and partly because they are governance failure (low social capital and poor institutional quality). But more importantly, the LHS of the decision tree allows for a much stricter control for country-specific (development) factors. I also add to the LHS "access to green technologies", a category that is missing in the OECD green growth diagnostics. However, this is by many scholars and policy makers identified as a major binding constraint for developing economies and should thus be included here.

Figure 4: Green growth diagnostics for eco-innovation



Given this re-organization of constraints it would be possible to run some tests which ones are actually binding. If indeed complementary resources are binding, the economy should be on the left-hand side of the EKC, indicating that low per-capita-income and hence the highly correlated

[5] To compare with the OECD diagnostic, just assume that appropriability would be the problem in the very classical sense of a negative environmental externality. Thus private returns would be lower than social returns. How can the OECD diagnostics then exclude the case that low economic returns are at the root of low green investments? The existence of a non-internalized externality can go hand in hand with too low returns. Thus, we have no clear indicators which can help to identify the binding constraints along the lines of the proposed decision tree unless we assume that all left-hand-side listed factors are constraining factors that override the externality problem. This seems not to be the view of OECD (2011a) as it allows for a plethora of factors constraining green growth simultaneously, thus contradicting the idea of a binding constraint.

variables infrastructure, human capital and access to green technology access are eventually binding constraints. Additionally, all indicators on infrastructure, human capital, technology level and access available as well as existing and new surveys on "binding constraints" help in judging whether or not the left-hand side is binding. Of course, some more differential diagnostics are needed to make sure that not the right hand side of the decision tree is the binding one. Such test could look at improvements in governance and policies to address market failures, such as environmental policies and relate it to the outcome. If changes on these areas have not resulted into major improvements on greening the growth, it is most likely that complementary economic resources are the major binding constraint.[6] Naturally, if lack of complementary resources is identified as binding, green growth policies should give strong priorities to these areas rather than, e.g., launching a costly system of financial incentives to set-up business networks etc.

If we find, however, that the left-hand side is not binding, then low appropriability of returns should be the major problem. Here it would be easiest to start with governance failures[7]. Data and analysis at the country level are readily available at an internationally comparable levels, such of the World Bank's regularly published governance indicators and "doing business" surveys and the increasing number of growth diagnostics studies in the spirit of Hausman et al. (2008). Additionally, the researcher can design own surveys covering the issues listed here more explicitly. Finally, "perverse subsidies" typically stick out and are indeed often an expression of favoring incumbents. However, here it is where the devil often lies in the detail, especially when many institutions at various levels (e.g. national, regional, local) are involved, often conducting contradicting policies. But at least, it should be possible to identify major governance constraints and their impact on "green" innovation. It should, however, be emphasized, that some of the items listed under governance failure are indeed very general ones and could hold back both dirty and green innovation. What the researcher must demonstrate in green growth diagnostics is that these failures are detriment to a greening of innovation. Governance failure should then be contrasted to market failure, allowing for differential diagnostics.

With respect to market failure, it cannot be stressed enough that negative externalities are **always** at the heart of the problem of too low eco-innovation or a not-green-enough growth path. Without externalities the problem would simply not exist. Externalities are a necessary condition for "dirty growth". However, it is not sufficient to internalize them to obtain green growth and intertemporal optimal allocation of resources. The point here is that even after proper internalization eco-innovation will be hold back. This is rather clear for barriers to competition. I will therefore highlight this issue for the cases of path dependencies of R&D.

Imagine all externalities of, say all CO_2 emissions are internalized and bad governance is not the problem. Would we than obtain more eco-innovations? A recent study on automotive patents by Aghion et al. (2010) sheds light on this issue. The authors investigate the industries patent history by distinguishing "clean" and "dirty" patents. In a cross-country panel data set they regress the current flow of clean-versus-dirty patents on the fuel price and the stocks of clean and dirty patents, respectively. The authors can establish a significant positive effect of fuel prices on cleaner

[6] For reasons of space I will not discuss here the whole process of (green) growth diagnostics. The reader is referred to Hausman et al. (2008) who discuss the diagnosing process in details.

[7] I use the term governance failure rather than government failure as it is done by OECD (2011) because I include here also low institutional quality and macro-economic instability.

innovation. Thus internalization would indeed redirect innovation into a cleaner direction, just as one would expect from the theory. However, even after controlling for the price effects, the author can show that companies with a dirty patent history are less engaged in clean patents, while company with a clean patent history are leaning towards clean patents. All the results are significant at a 1% significance level. The lesson is that internalization may be not enough. If an industry shows a strong path-dependence – especially when the industry has a history of dirty innovation – there is a strong case for policies other than price internalization to redirect innovation towards eco-innovation.

While the reasons for path-dependence as outlined above are knowledge spillovers within the company, such as a stock of engineers with a history of dirty or clean patents handing over their knowledge to the younger generation, network externalities refer to co-ordination failures with respect to other companies in the industries or – in a broader context – with the remaining supply chain or (potential) product-service and closed-loop systems. In such cases, eco-innovations would be profitable for each economic agent if all – or at least a critical mass – economic agents would embark on a certain eco-innovation. Individual actions, however, would not be profitable. Again it is clear that such problem can occur even after internalization – and they are the more likely to occur the higher the level of eco-innovation envisioned is (see Figure 2).

Of course, the green growth diagnostics advocated here is also not completely free of overlap and as the OECD's (2011) version also not entirely sequential. But neither is the Hausman et al. (2008) approach. However, with eco-innovation as the point of reference it should allow to conduct a well-structured analysis and a well-founded identification of binding constraints to eco-innovation and green growth with proper reference to country-specific circumstances.

4. Doing Green Growth Diagnostics in Practice: An Illustration for Climate Policy in China

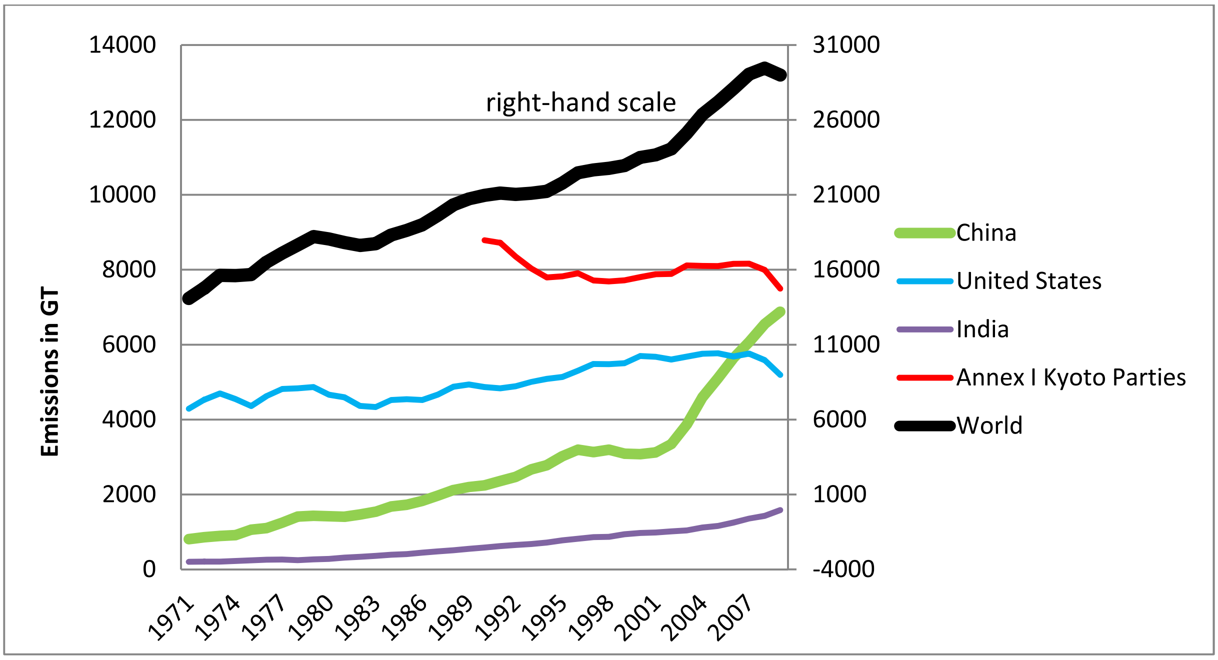
Is the green growth diagnostics model helpful in identifying binding constraint for greening growth in China? In the following I do not intend to deliver a full developed diagnostics – this would be beyond the scope of this short article. Instead, I will attempt to illustrate how the approach could be applied and I use the example of China's announced attempt to reduce CO_2 emissions in the coming year.

China is among the fastest growing countries of the world and can be reasonably expected to be determined (and eventually able) to remain on this high growth path for the next decade. The environmental consequences – especially with respect to CO_2 emission – will be dramatic unless China will be able to green its growth path substantially. China needs to decouple negative environmental effects from economic growth and is increasingly aware of this for at least two reasons: first, the local and regional consequences of pollution are directly and heavily impacting on its own population. Secondly, China is under severe international pressure to address its global environmental impact. Thus, shortly before the United Nations Climate Change Conference in Copenhagen 2009, China announced to reduce its CO_2 per capita emissions by 40-45% by 2020 relative to 2005 levels. China's new 12th Five Year Plan for 2011-2015 contains now a "green development" section. According to the new policy guidelines six strategic pillars, including climate change, are identified and binding targets on certain emissions are outlined. In particular, a reduction of CO_2 emissions per unit of GDP by 17% as compared to 2010 has now been targeted for 2015 (IEA 2011: 25).

If we look into the issue from the perspective of green growth diagnostics, it is helpful to have a look at the data of some comparators, too.

Whereas some slowdown in world emissions is visible, and even some first sign of a reductions in some countries which are not entirely caused by the recession in the aftermath of the financial crises, especially China continued to rapidly expand its CO2 emissions as shown in Figure 5.

Figure 5: CO_2-Emissions 1971-2009



Data Source: IEA (2011).

Table 2: CO_2 Emission for China and Selected Comparators 2009

	CO2 emissions in GT	in % of world total	Share in world population	Emissions per capita in tons	Emissions per US $ of GDP in tons	Emissions per PPP $ of GDP in tons
Country/Country Group						
China	6877	23,7	20%	5,1	2,17	0,55
United States	5195	17,9	5%	16,9	0,46	0,46
India	1586	5,5	17%	1,4	1,81	0,35
Annex I Kyoto Parties	7497	25,9	13%	8,4	0,45	0,38

Data Source: EIB (2011)

As Table 2 shows, in 2009 China was the top emitter of CO_2, followed by the United States and India. For reference I also include the country group that committed itself under the Kyoto protocol, the so-called Annex I Kyoto Parties.[8] Even relative to its share in world population, the average Chinese emits more than the average world citizen, though considerably less than the average US citizen and the average inhabitant of the countries participating in the Kyoto protocol.

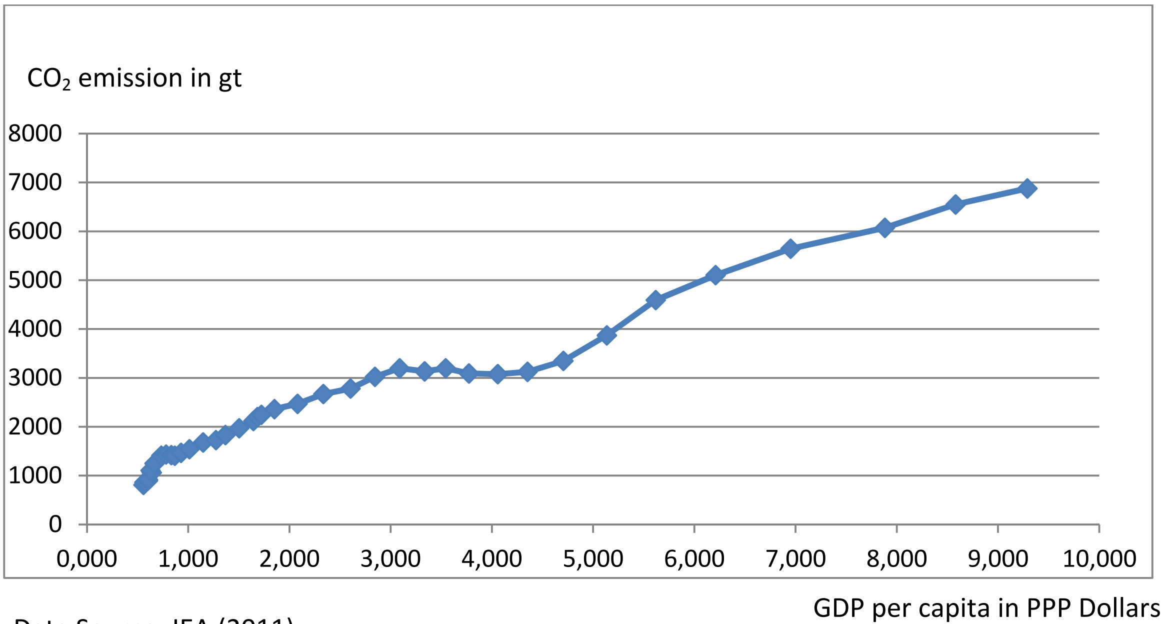
[8] Annex I Kyoto Parties include Australia, Austria, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein (not included in the data provided in Table 2), Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom.

Obviously two factors drive this development: fast economic growth and CO_2 intensity of production. While China will not compromise on economic growth, it is the “greening of growth” that is called for. The last two columns of Table 2 show the status quo in CO_2 intensity of production in comparison. It immediately reveals the visible emission bias of the Chinese economy, especially when calculated in terms of GDP measured in US-$. According to this measure, China`s CO_2 emission per US-$ of produced goods and services is more than four times higher than in the USA. As usual, current exchange rate converted-measures of output can be misleading in international comparisons. Moreover, most observers argue the Chinese RMB is undervalued with respect to the US-Dollar. Hence, the GDP figure used is too small to reflect the actual production. Using purchasing power parity (PPP) dollar is a widely used alternative. Using this yardstick, the inefficiencies do not disappear, but are considerably smaller. Given the strongly export-oriented character of the Chinese economy, the best indicator for a realist comparable picture of the CO_2 emission intensity of the Chinese economy may lay somewhere in the middle.

On a more political level the real question is what China means when it pledges to reduce CO_2 intensity by 2015 by 17%. Measured in US-Dollar this would mean a reduction from 2.17 to 1.7, just bringing it in line with the Indian performance, but still leaving it far away from the Kyoto participants standards. Calculated in term of PPP-measured GDP this would mean a reduction from 0.55 to 0.46, just bringing it in line with US standards, but again to Kyoto country standards it would still be a long way.[9]

In sum, whereas a global environmental Kuznets curve for CO_2 is eventually emerging – not least as a consequence of increasing global initiatives (Frankel 2009), the EKZ for China’s CO_2 emissions has not taken the inverted U-shape yet as Figure 6 clearly illustrates.

Figure 6: Environmental Kuznets Curve for CO_2 Emission in China 1971-2009



Data Source: IEA (2011)

[9] For a similar exercise which uses older data and different data source see Uwasu et al, (2010). The authors also provide a more detailed discussion of their exercise.

For green growth diagnostics it is now important to identify the most relevant sectors or industries areas that are responsible for the CO_2 intensity of the Chinese growth model. Table 3 gives the relevant information.

Tablle 3: Sectoral Biases in CO2 Emission for China and Selcted Comparators in 2009

	CO2 emissions in	in % of world total	Electricity and Heat Production		Manuf. industries and construction		Transport		*of which: road*	
Country/Country Group			in %	REB	in %	REB	in %	REB	in %	REB
China	6877	23,7	48,3	1,2	33,2	1,6	6,9	0,3	5,3	0,3
United States	5195	17,9	42,2	1,0	10,5	0,5	31,1	1,4	27,0	1,6
India	1586	5,5	54,0	1,3	21,8	1,1	9,5	0,4	8,5	0,5
Annex I Kyoto Parties	7497	25,9	40,0	1,0	16,7	0,8	22,3	1,0	19,4	1,2
World	**28999**	**100,0**	**40,8**	**1,0**	**20,2**	**1,0**	**22,6**	**1,0**	**16,8**	**1,0**

The "Revealed Emission Bias" (REB) is calculated as REB = $(E_{ij})/E_j)/(E_{iW}/E_W)$ with i=sector, j =country (group) and W=World
Data Source: EIB (2011)

The biggest contributors to China's emissions are the energy sector and – as expected – the manufacturing sector. I illustrate the biases in these sectors by using a variant of the Balassa revealed comparative advantage index, to show when a country has relatively more emissions in one sector than the rest of the world. This "revealed emission bias" (REB) exceed 1 when a country's emissions from a certain industries exceeds the emission contribution of that particular industry on a global scale, thus indicating a relative inefficiency that can eventually be overcome. It shows that the two largest contributors, manufacturing and energy, are also those with the highest relative inefficiencies and may thus require specific green growth diagnostics.

With respect to the manufacturing sector I will only make three short comments. First, it is obvious that China's growth model is focusing on manufacturing – and manufacturing is almost by definition energy intensive. As long as this continues, it is difficult to see that a CO_2 EKZ will any soon emerge. Second, and given that every industry might face different problems and has differing energy intensities (e.g. aluminum industry), it is advisable to have separate growth diagnostics for each of the major CO_2 emitting industries. Third, for green growth diagnostics it is important to see to what extent this manufacturing bias is a natural outcome or whether it is caused by some distortions in the economy. Without further comments or taking sides, the green growth diagnosing researcher might consider to follow up on the arguments raised in the most recent IMF Article IV report (IMF 2011: 20) which tend to locate the binding constraint on the RHS of the decision tree:

> "China's growth model relies on various low-cost factor inputs, including land, water, energy, labor, and capital. This offers Chinese firms a competitive edge and creates incentives for capital intensive means of production. Studies estimate the total value of China's factor market distortions could be almost 10 percent of GDP."

I will now turn to the energy industry to illustrate the workings of the green growth approach at the industry level further. It is useful to start with three observations: First, there is the strong bias in the Chinese production of energy towards coal. IEA (2011: 24) reports that "…nearly all of the 1990-2009 emissions growth from power generation derived from coal, although the emissions performance of coal-fired power generation has improved." As other forms of power generation are concerned, hydro power stands out, though nuclear energy as well as other renewable energy sources are growing too, though from a small base. Second, the energy mix differs very much across the provinces in China. While the northern, eastern and northeastern provinces are most heavily depending on coal, the northwestern, central and southern provinces are increasingly using hydro power (Huo et al. 2010). Third, and related to the former topic, renewable energies play an important role in China's energy policy strategy as the National Development and Reform Committee (NDRC) has already in its Medium and Long-Term Development Plan (NDRC 2009) set the goal to increase the proportion of renewable energy consumption to 15% of total energy consumption introduced. Moreover, on additional important goal of the plan is to develop and produce renewable energy equipment based on self-developed intellectual property.

Given these information a green growth diagnostic can start from the point of view of the eco-innovation approach and perform various diagnostics for the various levels of eco-innovation in the energy sector (see also OECD 2008 for a deeper discussion of eco-innovation in China). If we illustrate the diagnostics approach here, for instance, with the introduction of renewable energy, we could first look into the relevance of the binding constraints on the LHS of the decision tree. Given the policy determination and the availability of economic and financial resources, the evidence suggests that social and economic constraints may at the moment not the binding ones. China understands the need to green the energy sector and has also the economic resources to do so. Infrastructure, especially with respect to the grid are frequently mentioned as constraints, but could eventually be overcome over time when and as they become binding. This directs us immediately to the RHS of the decision tree.

As far as market failure are concerned the mispricing of energy and the lack of internalization of external cost is well-documented, not least in the previously quoted latest IMF (2011) Article IV report. Gradual adjustment of relative energy prices is thus envisaged in the coming years and will eventually relax this indeed binding constraint over time. As this process is threatening incumbents and eventually getting into contradiction with local and regional demands at the provincial level, governance failure could become potentially binding, too. The reform and re-adjustment process may thus involve a number of trial and errors processes where not-sufficiently-addressed market failure and governance failure can become binding in an alternating way.

The strength of the (green) growth diagnostics approach is that it provides a framework to analyze the alternative relevance of binding constraints over time. While it may now be most important to adjust relative prices closer to social costs this will soon also create additional governance problem. However, at some point greening of the energy sector will also face increasing bottlenecks in (grid) infrastructure, even if they are not binding yet. The particular value of the diagnostics approach is therefore not so much that it offers a new methodology, but rather that it provides a framework for a policy dialog amongst all parties concerned with a view on identifing most binding constraints in a particular area and at a particular time.

5. Conclusion and Outlook

A green growth diagnostics is feasible, sensible and useful to identify binding constraints to greening growth and eco-innovation. But it is neither something completely new nor a paradigm shift. For researchers, it can best been looked at as a directory to the increasingly growing jungle of environmental indicators. But its real value lies in facilitating a dialog between researchers, policy makers, the corporate sector and the civil society. Once we realize that, like in many other economic policy areas, political reform capital is a scarce resource, then an informed policy dialog becomes central for devising green growth strategies. A proper undertaken green growth diagnostics can reveal the binding constraints to greening growth and the cost and benefits of removing these constraints.

This article has suggested to focus the green growth diagnostics on the industry level and in particular on eco-innovations, defined in a broad sense. However, by following closely the OECD approach I have here – like OECD – adopted a national level perspective. While this is useful for a devising a national strategy as well as an intra- and inter-national policy dialogue, the approach almost completely ignores the global nature of international production. Consequently, this calls for a green growth diagnostics for global value chains. Next to identifying binding constraints it could provide an important instrument to structure the global dialog on greening global industries among the various stakeholders. However, this would lead us immediately to important issues regarding global governance of global value chains. But this is clearly beyond the scope of this short article.

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