Sustainable growth in South Africa: environmental and trade policy with directed technical change

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Abstract

This paper examines how a developing country can re-direct its productive comparative advantage in trade through technological investments, and how this influences environmental outcomes, both at the global and local level. In order to do so, we build a theoretical model of two regions, the North versus a country in the South richly endowed in fossil fuels, for instance a country in the BRICs [1], interacting through international trade. The South country initially builds its comparative advantage on industries that make intensive use of the fossil fuels. The North at some point becomes concerned with global pollution, which is mostly produced in the South, and tries with unilateral trade and environmental policies to shift the industrial production of the South away from globally polluting goods. The result of these policies, however, is that the Southern county shifts from the exploitation of a globally polluting resource to the depletion of its local environment, in order to retain its trade competitiveness, without any technological upgrading in other sectors. We then discuss what would be the appropriate policies from the perspective of the South country in order to remain competitive, face the environmental demands from the North and preserve its local environment.

Keywords: Developing countries; Environment; Innovation; Directed Technical Change; Comparative advantage.

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[1]This paper is part of a broader SNF research on the costs of transitioning to a green economy for South Africa, therefore this setting was initially thought for this country.

Introduction

Many developing countries consider green growth an important future priority in their development agenda, especially as the international community encourages a transition away from high Co2 emissions and it portrays the green economy as a panacea for solving issues of unemployment, sustainability and fairness (OECD 2012). The classical economic argument is that, as industrialized countries in the "North" demand more and more of global public goods as their income rises, and therefore push for international cooperation in green development paths, it should also promote green technology transfers and support R&D in green production techniques, both at home and in the polluting developing world. The European Union's Eco-Innovation Action Plan, for example, includes, among its actions, international cooperation with emerging countries such as China, India and Brazil, in order to create partnerships that favor eco-innovation (EU-ETAP 2004). This strategy should foster environmental sustainability and social inclusiveness, while combating climate change and other global environmental concerns (ADBI 2010).

However, electing a green growth path requires radical industrial transformations and changes in production, and the adoption of cleaner technologies imposes the re-training of human capital capable of using such technologies and the reallocation of inputs to new sectors. Overall, a structural transformation of this proportion can be extremely costly for a developing nation and might not be eschew from large forms of social disruption - historical examples are abundant, for example when Britain moved out of coal mining in the 1980s (Florio 2004). It is therefore important to examine how the transition to a greener economy would take place in a country already heavily invested in dirty production, which established its comparative advantage in international trade on the abundance of resources and where the whole economy has been built around fossil fuels extraction, processing and export. International environmental policies (for instance global pricing of carbon emissions) can produce very large economic and social shocks in emerging markets, that might be hard to compensate only through technology transfers from the EU or other rich nations.

There is a large literature in economics studying the interaction between economic development and environmental issues. Early work in resource economics examine how growth prospects are influenced by the depletion and degradation of natural resources (Dasgupta and Heal (1980); Hartwick (1977); Solow (1974)). The rising scarcity of natural resources generally results in increasing incentives to search for new technologies that will be less reliant upon natural resources. It has been well established in the literature that part of the problem of moving to green technologies is path dependence in innovation in "dirty" sectors (Acemoglu et al. (2012), Smulders and Egli (2011)). Moreover, the issue of transitioning to a greener wold while retaining competitiveness on global markets has also been explored in a comprehensive framework by Hémous (2013). Nonetheless, some important aspects have been overlooked in this strand of literature: first and foremost, even if the paper by Acemoglu et al. (2012) explores the possibility of owning an exhaustible resource, it does not consider that this could be the source of specialization of a country and therefore that it might be very hard to move to other, cleaner sectors. Secondly, even papers that consider issues to do with specialization like (Hémous, 2013), do not consider that a developing country might be pressured away from emitting pollutants that damage the global commons, but instead of switching to cleaner production it might simply start using more of the local environment in order to remain competitive.

Aim of the study

In this research, we model the challenges for an emerging country moving to a green economy pathway. We focus on the case of countries abundantly endowed with fossil fuel resources, such as Brazil, India, China, Russia and South Africa (the BRICs) or Middle Eastern countries. Consider for example the case of South Africa: this country is abundantly endowed with cheap coal, which it uses as a main source of energy and for export revenue [2]. Even if the government has made some clear statements about committing to climate change mitigation, abandoning coal for a country like South Africa would be tremendously costly - even if clean technologies were freely available.

Overall, for an emerging country to devise a sustainable path to green development, even with international support in the form of technology transfers, will be extremely complex. International green technology diffusion could be a useful element encouraging a path of low-carbon and energy-efficiency, but interestingly, unlike many other developing countries, South Africa does not suffer from lack of technological capacity or inability to raise finance, as it has been demonstrated by large-scale innovative projects developed in the past in the energy sector (Marquard, 2007).

The contribution of our model is to show what are the structural changes that a country like South Africa would need to undertake, should it decide to substantially modify its industrial

[2] Coal accounts for 70% of primary energy consumption, 93% of electricity generation and contributes 2.5 billion euros to foreign exchange revenues from exports. However, this implies very large emissions of CO2, with around 340 Mt per annum from fuel combustion, making South Africa the 15th largest emitter in the world (Eberhard, 2011)

structure away from coal. It shows what effects could have unilateral policies coming from richer nations, and what are some of the policy options for the government to counterbalance the demands from the "North", while preserving the competitiveness and local environmental quality of the developing country. It indicates that there is a risk of a *local* pollution heaven effect (not exactly the one mentioned by Copeland and Taylor (1995), more about this local effect is explained later) that makes international policies much less effective. The push towards cleaner sectors and technologies must come from within the developing country and must be compatible with maintaining trade competitiveness and a comparative advantage in some sectors and goods which are different from the North.

1 Model

We set up a discrete time, infinite horizon model with two regions of the world, North and South, two sectors, S and M, and three factors, labour, natural resources and scientists. The backbones of the model are similar to Hémous (2013). The production factors are fixed and the economy specializes according to an Heckscher-Ohlin model of comparative advantage in the production of goods that use intensively the factors that a nation owns abundantly (relative to the rest of the world) (Dornbusch et al., 1980).

1.1 Welfare

Welfare in the North and in the South is specular, and it consists of a discounted sum of utility from consumption and from environmental quality. For a given region this is

$$W^k = \sum_{t=0}^{\infty} \frac{1}{(1+\rho)^t} \frac{\upsilon^k (E_t^k)^{1-\eta}}{1-\eta} \left(C_t^k\right)^{1-\eta} \tag{1}$$

where the superscripts k refer to the country, either North or South, $k \in \{N, S\}$. Utility derives from consumption, C and from environmental quality, E. We allow for a possibility that the two regions may value the environment differently, so that the υ is region-specific.

1.2 Environment

Environmental quality for a given country, E^k, consists of local environmental quality and trans-boundary pollution, which for simplicity we assume is produced only in the South, because it is the only country that can make use of fossil fuels. It evolves according to the law of motion

$$E^k = (1 + \Delta)E_{t-1} - \delta Y_{RL}^k - \xi Y_{RG}$$

so that environmental quality depends on past environmental quality given some regeneration capacity, Δ, minus the damages of local and global pollution. The key aspect of environmental degradation here is that the South country can choose whether to deplete its fossil fuel resources, as its own source of comparative advantage, or, if forbidden to do so, to use up its local environment. This means polluting only locally, ruining local ecosystems which are hardly priced, using domestic common resources such as water in a order to retain the comparative advantage and not re-structure completely the domestic industry. In the case of South Africa and similar countries, this could for instance imply using carbon only for domestic purposes, or exporting it only to other African countries that do not have strict carbon policies.

In the model here we simplify the complex dynamics of Co2 and assume that, if the South decides to consume its local environment, the North is not damaged at all ($\delta = 0$ if $k = N$, because the North does not suffer from the local pollution produced in the South); in reality, it might be worse than that, and the global environment might still be partly hindered. ξ represents damage of global pollutants, which is assumed to be the same in both regions. Y_{RL} and Y_{RG} are productive inputs that make use of the fossil fuel resource, R, which gives rise to pollution. L and G respectively stand for local and global. The next subsection describes in detail the production structure of these economies.

Note that if environmental quality goes to zero, utility becomes zero as well, independently of the level of consumption. This corresponds to a scenario of an environmental disaster ($E = 0$).

1.3 Production

Both countries produce and consume a basket of final goods, C, which aggregates two types of goods produced, M, for manufactures that intensively use fossil fuels in their production, and S, for goods that are less resource intensive, such as services or light manufacturing:

$$C^k = \left(\mu (C_M^k)^{\frac{\sigma-1}{\sigma}} + (1-\mu)(C_S^k)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where C^k is the amount consumed in country k and σ is the elasticity of substitution between the two types of goods [3]. Both M and S are traded internationally, but they differ in the way they are produced.

Good S - The production of S-type goods does not involve the use of fossil fuels or other natural resources. This type of production can be identified with services, or light manufacturing. Therefore the production of this goods requires only labour and technological inputs, plus some S-specific intermediate goods, following a similar idea as in Acemoglu et al. (2012).

$$Y_S^k = L^{1-\beta}\left(\int_0^1 A_S^k (x_i^k)^\beta di\right) \tag{3}$$

Intermediate inputs x_i are produces and sold in a monopolistically competitive fashion as

$$x_{iS} = \psi(L)^{1-\beta} \tag{4}$$

Intermediates are not traded internationally and use the same factor share, $\beta^{\in}(0,1)$, as the final assembly of the S good. Intermediates are necessary for this model in order to ensure that the profits of any innovation or investment are appropriated by those entrepreneurs who produce an intermediate i.

Good M - M goods instead can be produced also using environmental resources (global or local). Therefore the total production of Y_M^k is a composite basket of the different production techniques:

$$Y_M^k = \left((Y_C^k)^{\frac{\epsilon-1}{\epsilon}} + \left((Y_{RG}^k)^\gamma + (Y_{RL}^k)^{1-\gamma}\right)^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{5}$$

The three possible production methods, $z \in C, RG, RL$, for this type of goods are then:

[3] We restrict our focus on the cases when goods are gross complements or Cobb-Douglas consumption, so that both goods are essential.

1. Not using any resource, just use labour and intermediates (machines), which would be the cleanest option (C).

$$Y_C^k = L^{1-\beta} \left(\int_0^1 A_C^k (x_i^k)^\beta di \right) \tag{6}$$

2. Using a resource that causes global pollution(RG)

$$Y_{RG}^k = R_G^\alpha L^{1-\beta-\alpha} \left(\int_0^1 A_{RG}^k (x_i^k)^\beta di \right) \tag{7}$$

3. Using a resource that causes only local pollution (RL)

$$Y_{RL}^k = R_L^\alpha L^{1-\beta-\alpha} \left(\int_0^1 A_{RL}^k (x_i^k)^\beta di \right) \tag{8}$$

Again, inputs are produced with same factor shares as in the final goods' production, so they are z-specific.

These production equations combine with he market clearing conditions for labour and resources and market clearing conditions for the quantity produced and quantity consumed of the different goods.

We do not distinguish a clean vs. dirty type of goods, because this would not easily map into anything clearly identifiable by the data. A priori, goods of type M can be either cleaner or dirtier than S-type, it just depends on what production technique is chosen to make them.

1.4 Innovation

In the above framework, innovation pushes the A technologies used for production (A_S, A_C, A_{RG}, A_{RL}). Technology for any of these sectors evolves according to the difference equation

$$A_{zit}^k = \left(1 + \varphi s_{zit}^k\right) A_{zi(t-1)}^k \tag{9}$$

for $z \in \{RG, RL, C, S\}$. The factor φ captures the effects of successful innovation, together with knowledge spillovers and decreasing returns to scale in innovation [4].

The crucial choice is then the allocation of a mass of scientists, s, operating in in sector z, on an input machine i, at every point in time. In every period, each scientist decides in which sector to operate, and then is randomly allocated one machine. Its chances of a successful innovation are $\eta_z \in (0, 1)$ and would produce an improvement of $1 + \gamma$ in the productivity of the machine. Then the productivity of all i machines in a sector can be aggregated to an average productivity of $A_{jt} = \int A_{ijt} di$.

Of course market clearing for the total mass of scientists, which is fixed, must hold as well in equilibrium.

2 Results without policy intervention

Without any policy intervention, the laissez faire equilibrium can be solved as follows: first of all, final goods producers maximize their profits choosing their inputs demand. If we plug their demand for inputs in the profit maximization of input producers, we can solve for the relative prices of goods in the various z sectors. This gives then the quantity of production, and therefore the relative profits of each sector. Scientists allocation is derived based on relative profitability of the various sectors, and is relative to that.

We expect that the South starts with RG, because by assumption it is the only one endowed with the resource, R, and the least costly way of using it is by creating global externalities. Hence the South specializes in goods of type M because RG is abundant and provides a comparative advantage in international trade.

Given the profitability of this sector, scientists are mostly allocated to these activities, so technology A_{RG} gets better, and cumulatively it improves over time. This is a classic case of *resource directed* technical change, which produces path dependency. A formal proof is provided in the Appendix.

Then North of course specializes in S, because it does not have the resources.

[4] A more complete characterization of this factor can be found in Hémous (2013).

2.1 Trade pattern

Given the above productive structure, the South exports M made with globally polluting resources, while the North exports S.

2.2 Innovation pattern

The innovation occurs in the exporting sector (or sub-sector) of each country (mostly) - so the North does A_S, and the South does A_{RG}.

2.3 Environmental outcomes

The equilibrium described above gives rise to an expected environmental disaster if innovation accumulates in the RG sector in the South and no feedback mechanism from Welfare internalizes the global externality.

The laissez-faire equilibrium is destructive for the global environment and inevitably leads toa catastrophe. If, however, the valuation of the environment for the North, $v^N(E^N)$, is higher than that of the South, and the government of the North decides to intervene to internalize the environmental externality, it is likely that the North will impose some unilateral policy to prevent disasters.

3 Policy intervention

The North aims at reducing global pollution,a nd in order to do so, it can use:

1. Ad valorem tariffs on dirty imports for mthe South Y_M;
2. A subsidy to the S technology at home, which then it somehow tries to transfer to the South, trying also to make the South switch to S production;
3. A ban on coal or specific taxes on fossil fuel content of imports.

The expected effect of 1. and 2. in combination is a swap in comparative advantages as in Hemous (2013). But it will take a lot of effort to revert comparative advantages, because the North does not have the resource and the South has all its competitive hedge due to R. This policy might be too costly for the North.

However, more simply, the North might want just to move the South away from producing global pollution, but still maintaining the same specialization patterns and comparative advantages: a ban on RG (coal for example), or tariff on carbon content on imports could do this. However the result of such intervention would be to switch the South's comparative advantage not to cleaner technologies, but to RL, a destruction of the local environment.

The South might then consider some other policy responses in the face of mounting environmental degradation at home: in the context of directed technical change, this amounts to sponsoring the C technologies for the same goods it already had a comparative advantage on. At the same time, this would not require any trade barrier or distortion.

3.1 Expected results

Differently from Hémous (2013), the North through its unilateral policies cannot achieve a reverse in trade patterns and specializations, but leave the South to produce M, just with technologies that do not pollute globally. The effect induced over Southern production is rather ambiguous: it can choose to switch to cleaner technologies, but it can also use its local environment, which could be much cheaper. Therefore what happens is that the South starts using the local environment in order to keep its competitive hedge in M. Scientists reallocate to this sector of production, therefore no clean innovation is encouraged without government intervention from the South. There is no scope for true technology transfers and diffusion from one country to another, as the two countries innovate in completely different sectors that what the other one uses to produce!

4 Conclusion

The case of South Africa and similar emerging markets heavily invested in fossil fuel production clearly exemplifies why technology diffusion alone might be insufficient to switch to green growth. These countries have built their comparative advantage on international markets in carbon-related industries and could not immediately compete with the North on other types of cleaner goods. What it really takes is not just a push from the North, in the form of carbon-related tariffs or bans, which would only encourage over-utilization of local environments in the South, but a comprehensive push towards directed technical change in the developing country itself, coupled with a complete understanding of the total costs borne by the country in abandoning coal, oil and globally polluting production techniques. The interaction with the North can then take the form of development aid, cooperation and technological partnerships.

For further extensions of this analysis, then, it will be necessary to examine the exact social costs that accrue to those developing countries that elect a green transition path - either because international prices of fossil fuels change, or as they elect to move to less polluting development. Many industrializing countries presents some peculiar social features, such as the high degree of unionization of mine workers, a marked level of inequality, possibly even inter-racial tensions (consider again the case of South Africa, with its past history of apartheid). Future work will consist of exploring the dynamics of labour adjustment costs and potential social disruption and conflict, which are typically unaccounted for in models of innovation, environmental and trade policies.

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