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Spillovers from clean versus dirty technologies and growth: implications for macro-modelling

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SEVENTH FRAMEWORK PROGRAMME

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Spillovers from Clean versus Dirty Technologies and Growth: Implications for macro-modelling

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1 Introduction

Our recent work (Dechezlepretre, Martin & Mohnen, 2014, DMM) shows that clean innovation generates higher spillovers than dirty innovation. This could imply that shifting resources from dirty R&D to clean via a policy intervention can generate higher growth at th emacro level. However, the question arises what is driving this spillover gap? DMM explore explanations such as the suggestion that clean technologies are more general purpose or more original without much success. This leaves the explanation that spillovers - per innovation - are larger simply because clean technologies are a relatively un-explored field and there are decreasing returns to spillovers. Hence, what we measure is the higher marginal effect, however this advantage will dissipate once clean expands.

However, an implication of the presence of spillovers with decreasing returns is the possibility of multiple market equilibria some of which are inferior. Hence, if the economy is locked in an inferior equilibrium a policy intervention can lead to sustainable welfare improvement. In this note we develop a simple model that illustrates this.

2 A simple model

Consider a simple economy with a continuum of firms on a unit interval. Each firm i sells an output of Q_{it} on a competive market at price P_i which we normalize to 1 for simplicity - i.e. $P_{it} = 1$.

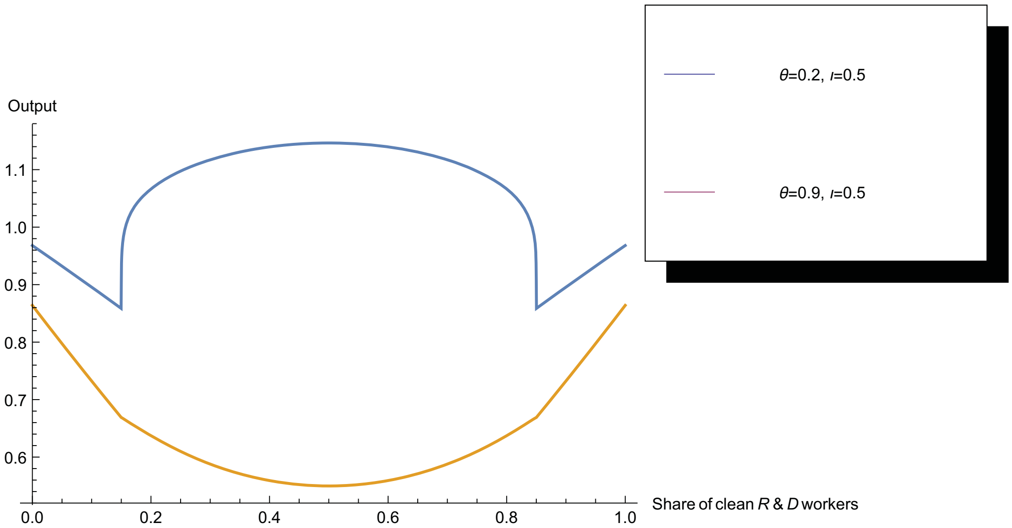
Output can be produced using either a clean or a dirty production process which are perfectly substitutable; i.e.

$$Q_{it} = Y_{iCt} + Y_{iDt}$$

where Y_{iCt} is the output from the clean and Y_{iDt} the output from the dirty process. Each process can be described by the following production function: $Y_{izt} = \Xi_{zt} s_{izt}^{\iota}$ for $z \in \{C, D\}$ where s_{izt} is employment of R&D workers by an individual firm in a particular technology type at time t and $0 < \iota < 1$. Ξ_{zt} captures spillover effects. We assume that a process is more productive if in the previous period more workers were employed in this particular process; i.e.

$$\Xi_{zt} = (s_{z,t-1} - \xi_0)^{\theta}$$

Figure 1: Output as a function of the share of clean R&D workers



Notes: $\xi_0 = 0.15$

where s_{zt-1} are is the aggregate employment of researchers in technology z in the prveious period. We assume that before spillovers arise there needs to be a minimum "critical mass" ξ_0 of activity in a technology field. This is a simple way to model a potential lock-in in a particular technology type.

Let's normalise the total supply of R&D workers to 1; i.e. $s_{C,t} + s_{D,t} = 1$.

We can then write the total output $Q_t = \int_0^1 Q_{it} di$ of this economy as a function of share of R&D workers that are employed in clean technologies in a steady state, $s_{Ct} = s_C$ for all t.

$$Q = (\xi_0 + s_C)^\theta s_C^\iota + (\xi_0 + 1 - s_C)^\theta (1 - s_C)^\iota$$

Notice that if the spillover effects as well as R&D productivity is sufficiently decreasing returns to scale - i.e. $\theta + \iota$ sufficiently small - this becomes a concave function with an internal maximum at $s_C = 0.5$ as illustrated in Figure 1.

Hence, in the high returns to scale case the social planner - ignoring any environmental costs - would choose either the 100% clean or 100% dirty equilibrium - assuming both technologies are entirely symmetric, which might not be the case in practice. In the low returns to scale case the social planner would choose $s_C = 0.5$ in the long run.

Now let's consider how private firms would behave. The profit maximization problem becomes

$$\max_{s_{Cit} s_{D_{it}}} \{Q_{it} - (s_{Cit} + s_{Dit}) W_t\}$$

where W_t is the wage of R&D workers. This leads to the following first order conditions:

$$\iota \Xi_{Cit} s_{Cit}^{\iota-1} \leq W_t \Rightarrow s_{Cit} = \left(\frac{W_t}{\iota \Xi_{Cit}}\right)^{\frac{1}{\iota-1}} \tag{1}$$

$$\iota \Xi_{Dit} s_{Dit}^{\iota-1} \leq W_t \Rightarrow s_{Dit} = \left(\frac{W_t}{\iota \Xi_{Dit}} \right)^{\frac{1}{\iota-1}} \tag{2}$$

There are three potential cases:

1. Firms invest only in clean
2. Firms invest only in dirty
3. Firms invest in both technology types

In the latter case equations 1 and 2 hold with equality. To figure out the R&D worker's wage we have to use the labor market equilibrium, which implies:

$$\left(\frac{W_t}{\iota \Xi_{Cit}} \right)^{\frac{1}{\iota-1}} + \left(\frac{W_t}{\iota \Xi_{Dit}} \right)^{\frac{1}{\iota-1}} = 1$$

so that

$$W_t = \iota \left(\Xi_{Cit}^{\frac{1}{1-\iota}} + \Xi_{Dit}^{\frac{1}{1-\iota}} \right)^{1-\iota}$$

Plugging this back into equation 1 leads to an expression for this periods employment share in clean as a function of last periods share:

$$s_{Cit} = \frac{\Xi_{Cit}^{\frac{1}{1-\iota}}}{\Xi_{Cit}^{\frac{1}{1-\iota}} + \Xi_{Dit}^{\frac{1}{1-\iota}}} = s_{Ct} \tag{3}$$

where the second equality follows from working with a unit mass of identical firms. Hence, we can use this equation to study how the economy evolves over time and what fixed point it might converge to.

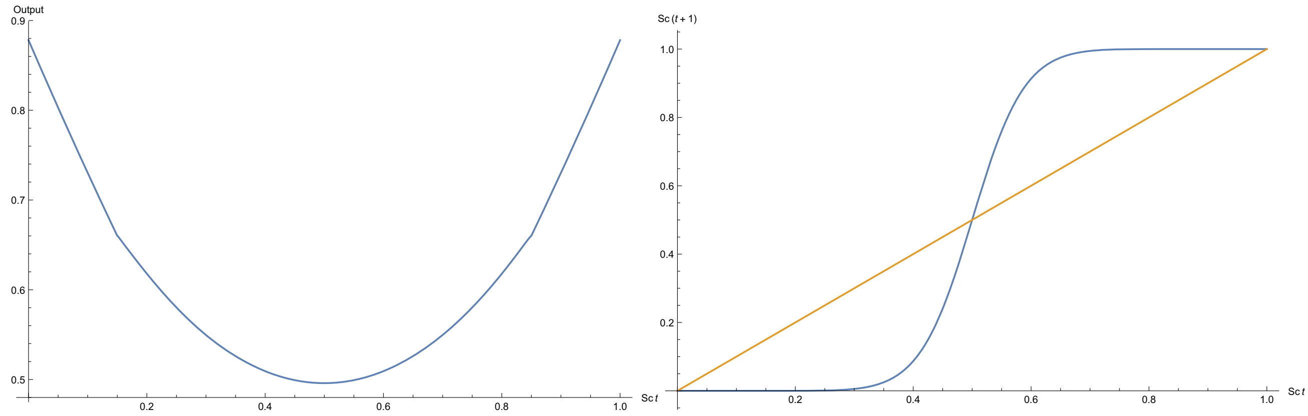
Figure 2 (in column 2 of each panel) plots equation 3 for various assumptions about the returns to scale (blue lines). The first column plots the steady state output function for each case. In Panel (a) we look at the case of rather high returns to scale ($\theta + \iota > 1$). The right figure showing the transition function 3 also plots 45 degree line (orange). If the transition function is below the 45 degree line the share of clean workers - absent any government intervention - will decline. If it is above 45 degrees it will increase. Hence the figure suggests that as long as $s_{Ct} < 0.5$ the share of clean workers decline over time - i.e. $s_{Ct+1} < s_{Ct}$ - so that the economy converges to the 100% dirty steady state. Equally, it will converge to the 100% clean steady state if $s_{Ct} > 0$. In panel b we consider a case with lower returns to scale $\theta = 0.3$, $\iota = 0.6$. This makes the steady state output curve concave with a global maximum at $s_C = 0.5$. Also note from the right figure in panel b that while $s_C = 0.5$ is globally optimal it is not a stable equilibrium; i.e. if in previous years resources dedicated to clean R&D are only slightly smaller than 0.5 then the economy will eventually converge to the 100% dirty equilibrium.

In panel c we report figures with combined returns to scale that are even lower ($\theta = 0.26$, $\iota = 0.3$). Notice that now the gobal maximum at $s_C = 0.5$ becomes even more pronounced. Moreover, it becomes locally stable; i.e. as long as the economy moves close enough to $s_C = 0.5$ it converges to the global maximum.[1]

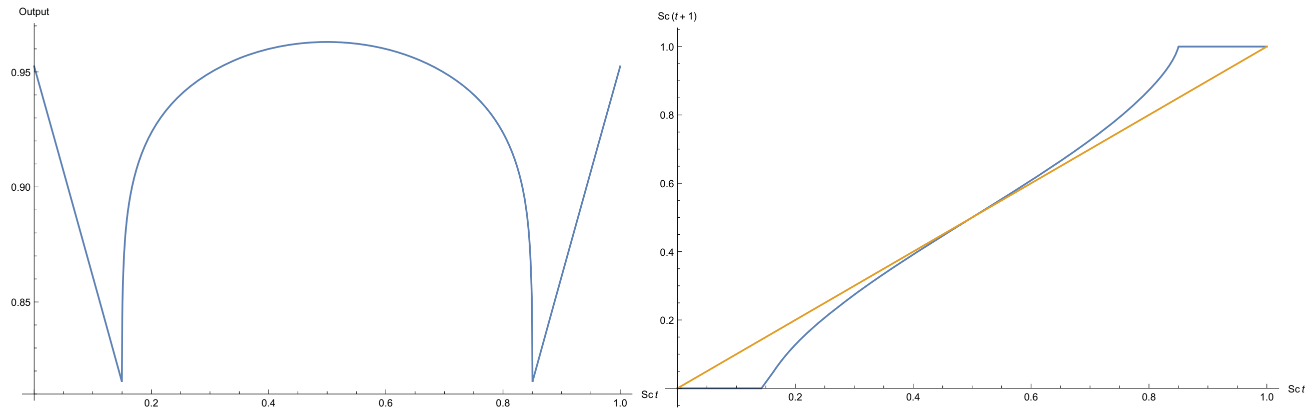
[1] In the appendix we provide exact conditions ensuring local stability.

Figure 2: Steady state output and transitions for various scenarios

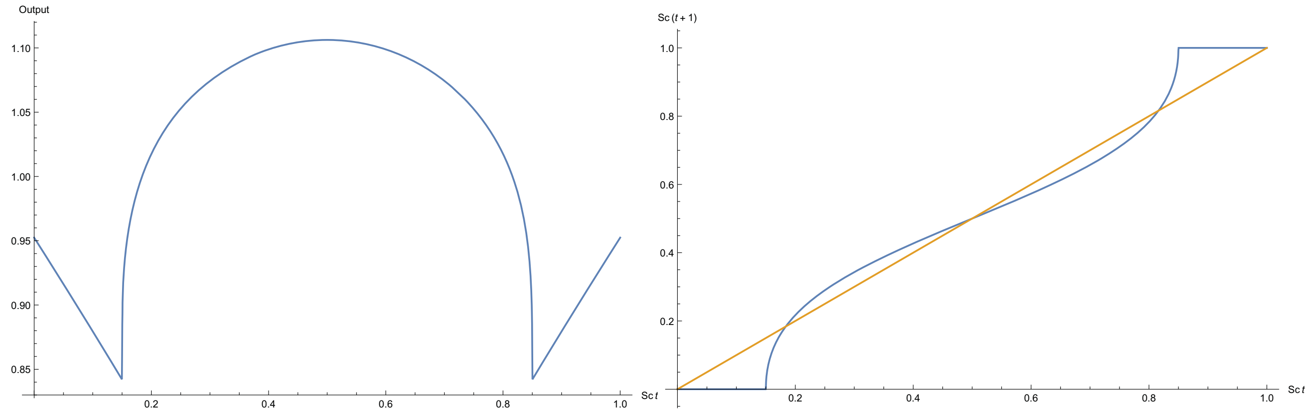
(a) $\theta = 0.8$, $\iota = 0.8$



(b) $\theta = 0.3$, $\iota = 0.6$



(c) $\theta = 0.26$, $\iota = 0.3$



Notes: $\xi_0 = 0.15$ in all cases.

3 Discussion and conclusion

Consider a scenario where the economy is initially in a 100% dirty equilibrium. A policy that moves the economy into a 100% dirty equilibrium has the potential to produce short term benefits in cases (b) and (c) as the output would at least temporarily be higher while moving trough the intermediate equilibrium. Importantly, this would be the case even though there is no permanent spillover advantage of clean technologies. Rather, clean technologies benefit from high marginal spillover rate as the clean knowedge stock is still small. However, the effect depends crucially on the returns to scale parameters of both the private knowledge generation function as well as the spillover function. This raises the question which kind of parameterization is most appropriate for real economies. It is beyond the scope of this paper to answer this question definately. However, our earlier work on the automotive industry (Aghion et al, 2012, ADMHV) provides some parameter estimates that can losely be interpreted as the scale parameters used here. Specifically, using parameters from the main regression results in ADMHV[2] would suggest a value of 0.26 for the spillover parameter θ and 0.30 for ι.[3]. In other words, this corresponds to the case depicted in panel (b). Hence, this would suggest that we are in situation where growth effects are possible. Having said that, a number of cuationary remarks are in order. Firstly, the economic model introduced here is indeed very simple and our calibration exercise very "back of the envelope" indeed. Before jumping to quick conclusion the spillover effects discussed here should be introduced in more elaborate macro and growth models and more careful calibrations should be undertaken. Secondly, even if indeed we are in an economy that broadly corresponds to the one depicted in panel (c), growth effects are still not guaranteed. In addition to establishing the structure of the economy we would have to determine our initial state. If we are close to the intermediate equilibrium already and from a climate point of view the objective is to move to an economy that is fully clean then further growth effects are unlikely even in case (b). Hence again this is best discussed within the context of a more realistic macro model.

References

[Aghion et al., 2012] Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., and Reenen, J. V. (2012). Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry. Working Paper 18596, National Bureau of Economic Research, forthcoming Journal of Political Economy.

[Antoine Dechezleprêtre, 2014] Antoine Dechezleprêtre, Ralf Martin, M. M. (2014). Knowledge spillovers from clean and dirty technologies. CEP Discussion Papers CEPDP1300, CEP.

A Stability of internal equilibrium

In this section we provide the formal criterion for the simple economy developed above to have a locally stable intermediate equilibrium.

Note that

[2]From the clean equation in Table 3

[3]i.e. using the "own stock" parameter from ADMHV

$$\frac{\partial s_{Cit}}{\partial s_{Ct}} = \frac{\frac{1}{1-\iota}\Xi_{Cit}^{\frac{1}{1-\iota}-1}(\xi_0+s_{Ct-1})^{\theta-1}\theta}{\Xi_{Cit}^{\frac{1}{1-\iota}}+\Xi_{Dit}^{\frac{1}{1-\iota}}} - \frac{\Xi_{Cit}^{\frac{1}{1-\iota}}}{\left(\Xi_{Cit}^{\frac{1}{1-\iota}}+\Xi_{Dit}^{\frac{1}{1-\iota}}\right)^2}\left(\frac{1}{1-\iota}\Xi_{Cit}^{\frac{1}{1-\iota}-1}(\xi_0+s_{Ct-1})^{\theta-1}\theta - \frac{1}{1-\iota}\Xi_{Dit}^{\frac{1}{1-\iota}-1}(\xi_0+1-s_{Ct-1})^{\theta-1}\theta\right)$$

$$\left.\frac{\partial s_{Cit}}{\partial s_{Ct-1}}\right|_{S_{Ct-1}=0.5} = \frac{\theta}{1-\iota}\frac{0.5}{\xi_0+0.5}$$

Hence

Thus if $\frac{\theta}{1-\iota} \times \frac{0.5}{\xi_0+0.5} < 1$ and therefore $\theta < \frac{\xi_0+0.5}{0.5}(1-\iota)$ the economy (at least locally) stable around an equilibrium of $s_C = 0.5$